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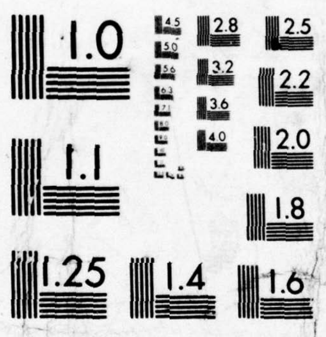

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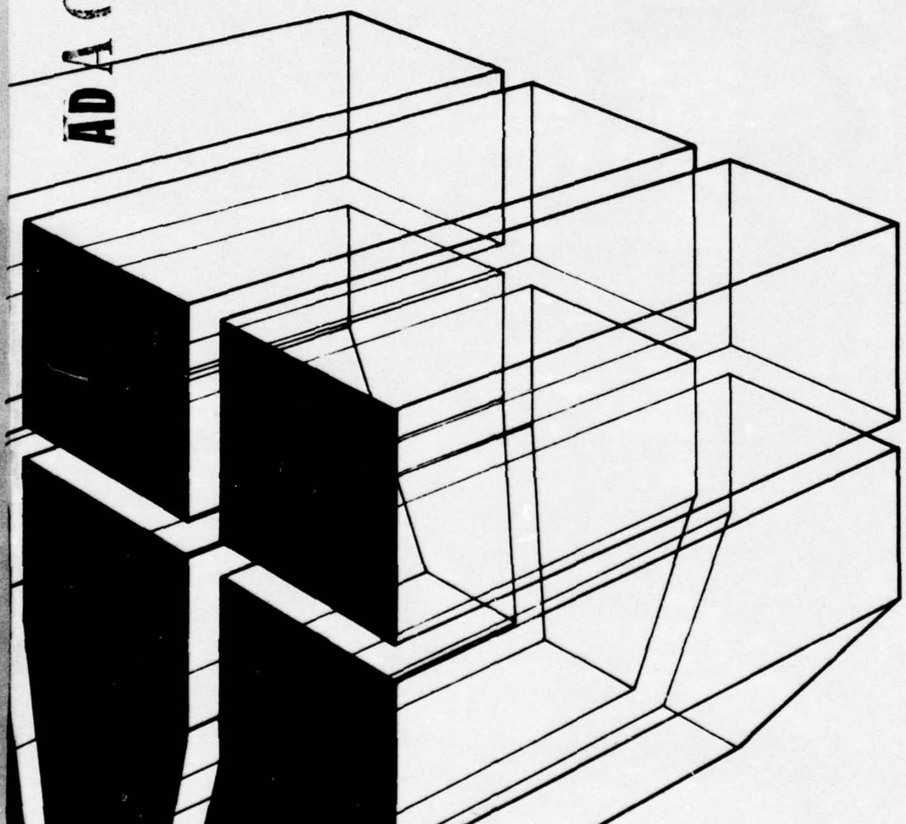
TECHNICAL REPORT N-11
November 1976
Characterization of Wastes From Army Installations

WATER/WASTEWATER SURVEY GUIDELINES



by
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report—one of a series of three which supply the means for gathering background data on solid waste, air, and water/wastewater—provides assistance in planning and performing water/wastewater surveys. It provides the format for planning an appropriate survey given a specific need for data. The types of surveys covered include regional and installation surveys designed to gather background information, and regulation compliance, waste source evaluation, and ambient water quality

Block 20 continued.

evaluation surveys, which provide information for regulation compliance inquiries, environmental impact analyses, problem characterizations, and design analyses. Additionally, the report provides background information on performing mass balances, developing sampling schedules, selecting sampling points, evaluating wastewater sources, and taking flow measurements.

FOREWORD

The U.S. Army Construction Engineering Research Laboratory (CERL) conducted this study for the Directorate of Military Construction, Office of the Chief of Engineers (OCE), under Project 4A162121A896 "Environmental Quality for Construction and Operation of Military Facilities"; Task 01, "Environmental Quality Management for Military Facilities"; Work Unit 004, "Characterization of Wastes From Army Installations." The QCR is 1.03.006(3).

V. Gottschalk was the OCE Technical Monitor.

The study was performed by the Environmental Engineering Team (ENE), Environmental Division (EN), CERL. B. A. Donahue was the CERL Principal Investigator and G. W. Schanche was the Associate Investigator. The authors wish to acknowledge Mr. J. Matherly and Dr. Yeun C. Wu for their assistance in preparing this report. Administrative support and counsel provided by Dr. R. K. Jain, Chief of EN, and Mr. W. J. Mikucki, Acting Chief of ENE, is gratefully acknowledged.

COL J. E. Hays is Commander and Director of CERL and Dr. L. R. Shaffer is Deputy Director.

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WATER/WASTEWATER SURVEY GUIDELINES

1 INTRODUCTION

Background

Recent environmental legislation and subsequent reporting requirements have produced a need for background data on pollutant emissions from Army installations.

AR-200-1,[1] issued by the Department of the Army, requires compliance with federal, state, interstate, and local standards for water emissions and ambient water quality. In accordance with Subpart C of the regulation, installation Directorates of Facilities Engineering (DFAE) must identify sources of water pollution and submit reports on pollutant emissions. Installations which do not meet current standards must furnish an Environmental Pollution Control Report (RCS DD-I&L (SA) 1088) proposing remedial measures for the pollution problem. The Environmental Protection Agency (EPA) also requires all federal facilities to obtain National Pollutant Discharge Elimination System (NPDES) permits for all discharges from point sources, to submit a periodic NPDES monitoring Report (RCSEPA-1002), and to report semiannually on the status of water pollution control as part of the Environmental Protection Control Report (RCS DD-1 & L(SA) 1088). (See the appendix for a brief history of recent environmental legislation.)

These reporting requirements pose a problem to installation personnel since comprehensive guidance is not available for defining water pollution emissions at gross and detailed levels. In response to this problem, this report provides installation personnel with guidance for gathering data on the water environment. This report is one of a series of three reports which supply the means for gathering background data on solid waste,[2] air,[3] and water/wastewater.

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[1] *Environmental Protection and Enhancement*, AR-200-1 (Department of the Army, December 1975).

[2] G. Schanche, L. Greep, and B. Donahue, *Installation Solid Waste Survey Guidelines*, Technical Report E-75/ADA018879 (Construction Engineering Research Laboratory [CERL], 1975).

[3] G. Schanche and B. Donahue, *Air Pollution Survey Guidelines for Army Installations*, Technical Report N-5 (CERL, 1976).

Objective

The objective of this report is to provide installation DFAE personnel with guidance for planning and performing water/wastewater surveys. The data gathered in the surveys can be used to facilitate environmental report preparation, indicate possible corrective measures for pollution problems, aid in preparing environmental impact assessments and statements, and assist in effectively contracting for and soliciting expert assistance in solving water pollution problems.

Approach

Data and informational requirements of installation personnel were identified by reviewing and assessing reports required by recent environmental legislation. Methodologies were developed to assist installation personnel in efficient gathering of necessary data and information on potential sources of water pollution. Specific sources of pollution and their likely types of emissions are described qualitatively.

Scope

These guidelines serve as a basis for improving data gathering. They present an organized system of survey planning (Chapter 2), mass balance investigations (Chapter 3), waste source descriptions (Chapters 4 and 5), sampling program design (Chapter 6), and water/wastewater flow measurement (Chapter 7). References listed in the Bibliography contain detailed background information for specific areas.

It should be noted that because of the many types of surveys which can be undertaken, these guidelines provide only conceptual guidance, rather than specific directions.

2 SURVEY PLANNING

Two basic types of survey data can be collected: background information, which gives a general overview of the water quality situation; and specific information, which details a particular problem. Regional and installation surveys furnish background information, while regulation compliance, waste source evaluation, and ambient water quality surveys provide specific data.

Background Information

Regional or installation surveys are performed to define the regional water quality setting and the installation's role in it. These surveys gather background and historical information about static or slowly changing elements of the water quality setting.

The **regional** survey defines the regional water environment by identifying major watersheds, defining major water uses, and locating major wastewater sources. The installation's role in the regional water system can be defined by interpreting survey information. For example, water bodies directly affected by installation activities can be identified by defining watershed drainage divides. Potential pollution problems can be anticipated by defining major downstream water uses and noting their quality and quantity requirements. Potential pollutants entering the installation can be identified by understanding the characteristics and location of upstream waste sources. The regional survey also identifies all regional regulatory agencies and the extent of their regulatory powers.

The **installation** survey defines the installation's water quality situation by dividing the installation into perennial stream watersheds and identifying land uses, wastewater producers, and water uses within each watershed. The survey data thus can provide a preliminary understanding of the factors controlling the installation's water quality. By providing an understanding of wastewater discharge characteristics, the survey also can help pinpoint potential sources of a specific problem pollutant quickly, thus hastening resolution of the problem.

Background information from these two types of surveys is very useful in furnishing the user with an understanding of the installation's role in regional water quality and its potential for impacting that quality. Such an understanding is basic to effective and informed cooperation by Army installations in achieving and maintaining the desired regional water quality.

Specific Information

Specific evaluations provide the user with the detailed information necessary for solving a specific problem. Because this type of information is highly dependent on the situation, almost all the data must be collected at the time it is needed. The four basic reasons for specific evaluation are: regulation compliance, environmental impact analysis, problem characterization, and design analysis. Three survey systems—the regulation compliance, waste source, and ambient water quality surveys—have been developed for use individually or in combination to gather the information required for these evaluations.

A **regulation compliance** evaluation is required to determine whether a particular discharge complies with regulations. Executive Order 11752 states that all federal facilities must comply with all ". . . federal, state, interstate, and local substantive standards and substantive limitations. . . ." The regulation compliance survey outlined in this report is useful for determining the extent of compliance at an existing discharge point (outfall). The waste source survey can be used to pinpoint the process or conditions responsible for any noncompliant discharges, and the ambient water quality survey can be used to check compliance with minimum water quality regulations established for a particular stream.

The purpose of an **environmental impact analysis** is to evaluate the potential effects of proposed or current activities on various aspects of the environment. In evaluating the effect of current activities on water quality, the regulation compliance survey can be used to identify violations of regulations, while the ambient water quality survey can be used to determine impacts of current activities on the receiving water. In evaluating proposed activities, the ambient water quality survey can be used to establish the background conditions and the waste source survey can be used to predict waste loadings from the proposed activity.

A **problem characterization** evaluation is performed to define a problem's scope and the factors that cause the problem. The waste source survey can be used to evaluate process-related problems, while the ambient water quality survey can be used to evaluate receiving-water problems.

The purpose of **design analysis** is to gather information on which to base design decisions regarding management systems and hardware systems. Management design decisions generally concern allocations of limited resources, evaluation of the adequacy of current systems, and development of new systems. The waste source, ambient water quality, and regulation compliance surveys can supply useful information for establishing funding allocation priorities and designing new management systems. The ambient water quality survey provides information

for allocating water resources and for judging the effectiveness of current water pollution control programs.

In designing wastewater treatment systems, selection of appropriate hardware components requires information on the characteristics of the wastewater to be treated and the quality of the effluent to be produced. In this capacity, the waste source survey supplies the necessary information about the wastewater characteristics, the regulation compliance survey provides information about the applicable water quality standards, and the ambient water quality survey provides information about the waste assimilation and hydrologic characteristics of the receiving water.

Survey Planning Flow Charts

Figures 1 through 8 are annotated flow charts to be used as guides in planning water/wastewater surveys. Before the flow charts can be used, a specific need for water-related information must be defined. Once this is accomplished, the flow charts provide step-by-step guidance in planning the appropriate type of survey for gathering the required information.

Figure 1, the survey planning master flow chart, directs the user to the appropriate flow chart for the type of survey(s) which will meet his needs. Figures 2 and 3 detail the sequence of steps required to complete regional and installation surveys, respectively; Figure 4 provides the general outline for a regulation compliance survey; Figures 5 and 6 list the specific steps to follow for the two types of regulations—stream standard and effluent standard (defined in the appendix); and Figures 7 and 8 contain instructions for completing waste source evaluation and ambient water quality surveys, respectively.

The flow charts also identify portions of this report which are applicable to planning specific parts of a water/wastewater survey.

The flow charts have two fundamental limitations. First, no mention is made of specific survey objectives. It is assumed that the flow charts will not be consulted until there is a specific need for information, which implies establishment of certain survey objectives. Second, the flow charts do not mention resource allocation for survey performance. It is assumed that background information can be gathered by any competent individual. Field investigations, however, should be handled by an experienced professional—either in-house or on contract. Survey planning and data interpretation should be performed cooperatively by the survey output user(s) and the experienced professional. Actual allocations of manpower, funds, and equipment depend on the size and scope of survey and time constraints. Large surveys having a broad scope and short completion time are generally the most expensive.

3 WASTEWATER MASS BALANCE

The mass balance approach is a systematic method defining the working of a particular system. The characteristics of the system are defined by determining the material inputs and outputs for each system element. The difference between inputs and outputs represents materials which are consumed or wasted by the system (Figure 9).

In wastewater investigations, the mass balance approach is used to define water use and probable characteristics of the resulting wastewater. This approach allows the investigator to understand the process workings, i.e., the inputs and outputs of a given process, and provides a means for accounting for all water and materials used in the system.

Surveys likely to employ mass balance procedures include regulation compliance surveys, waste source evaluation surveys, and some ambient water quality surveys.

The wastewater mass balance procedure has a qualitative aspect, in which existing information is used to define wastewater production and characteristics, and a quantitative aspect, in which field data are used to quantify wastewater characteristics. The steps involved in performing a wastewater mass balance are described below.

Definition of Scope of Investigation

The first step is to define the objectives of the survey, and the location and extent of the system under investigation, in order to establish the scope and limits of the investigation. Survey objectives fall into four basic categories: regulation compliance, problem characterization, design analysis, and environmental impact analysis.

Regulation compliance surveys are performed primarily to document compliance with specific regula-

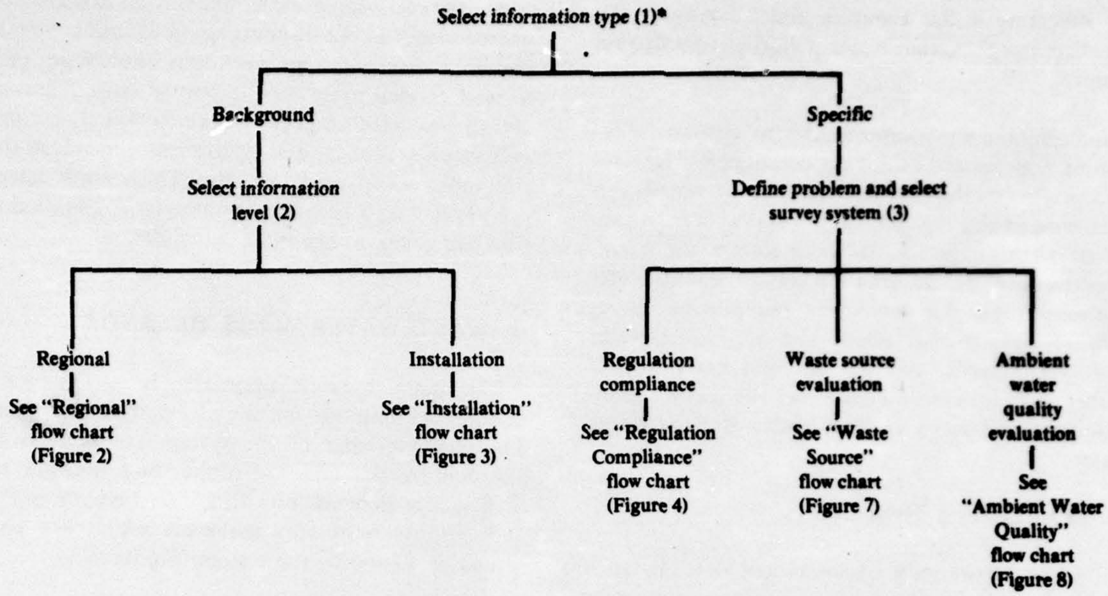

Figure 1. Survey planning master flow chart.

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*Numbers in parentheses refer to annotations which follow Figure 8.

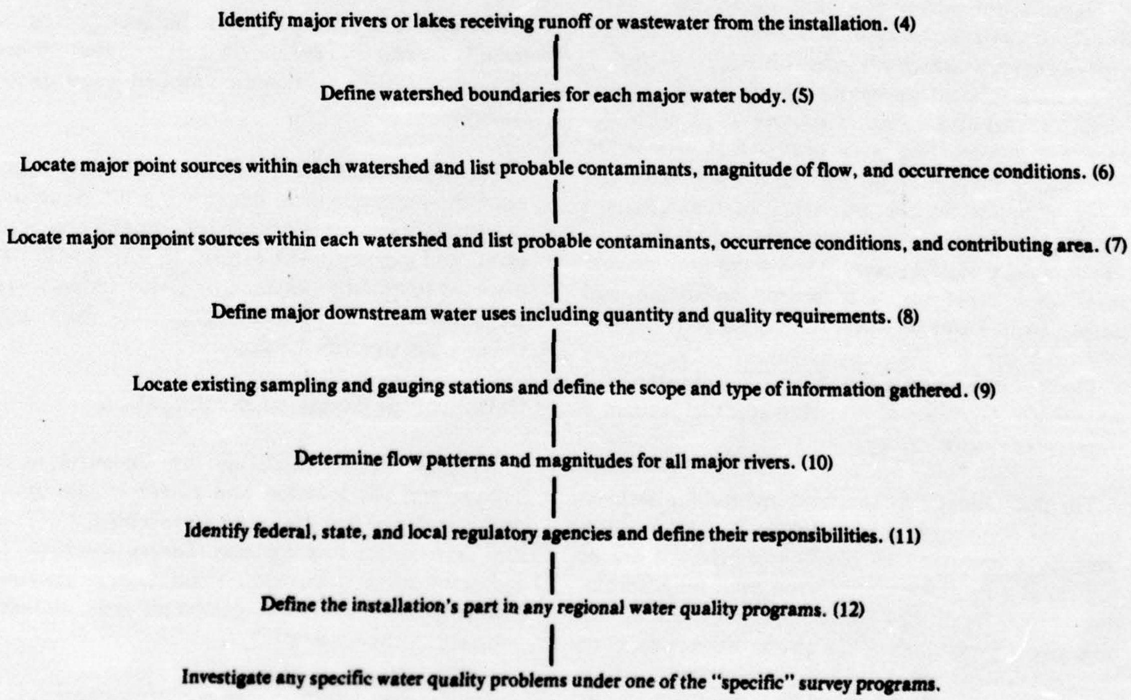

Figure 2. Regional survey planning flow chart.

Locate all perennial streams and lakes on the installation. (13)

Define the watershed boundaries for each identified water body. (14)

Identify major land uses within each watershed and define area devoted to each use. (15)

Locate point wastewater discharges within each watershed and define magnitude, occurrence conditions, and probable contaminants. (16)

Locate unconfined wastewater discharges within each watershed and define probable contaminants, occurrence conditions, and contributing area. (17)

Identify major water uses within each watershed and define usage patterns and magnitude. (18)

Determine flow patterns and magnitudes for all identified streams. (19)

Locate sources of existing information and define the scope and type of information gathered. (20)

Investigate any specific water quality problem under one of the "Specific" survey programs.

Figure 3. Installation survey planning flow chart.

Identify regulation source. (21)

Identify area(s) of questionable compliance. (22)

Select parameters to be investigated. (23)

Identify type of regulation. (24)

Stream standard

See "Stream Standard" flow chart (Figure 5)

Effluent standard

See "Effluent Standard" flow chart (Figure 6)

Figure 4. Regulation compliance survey planning flow chart.

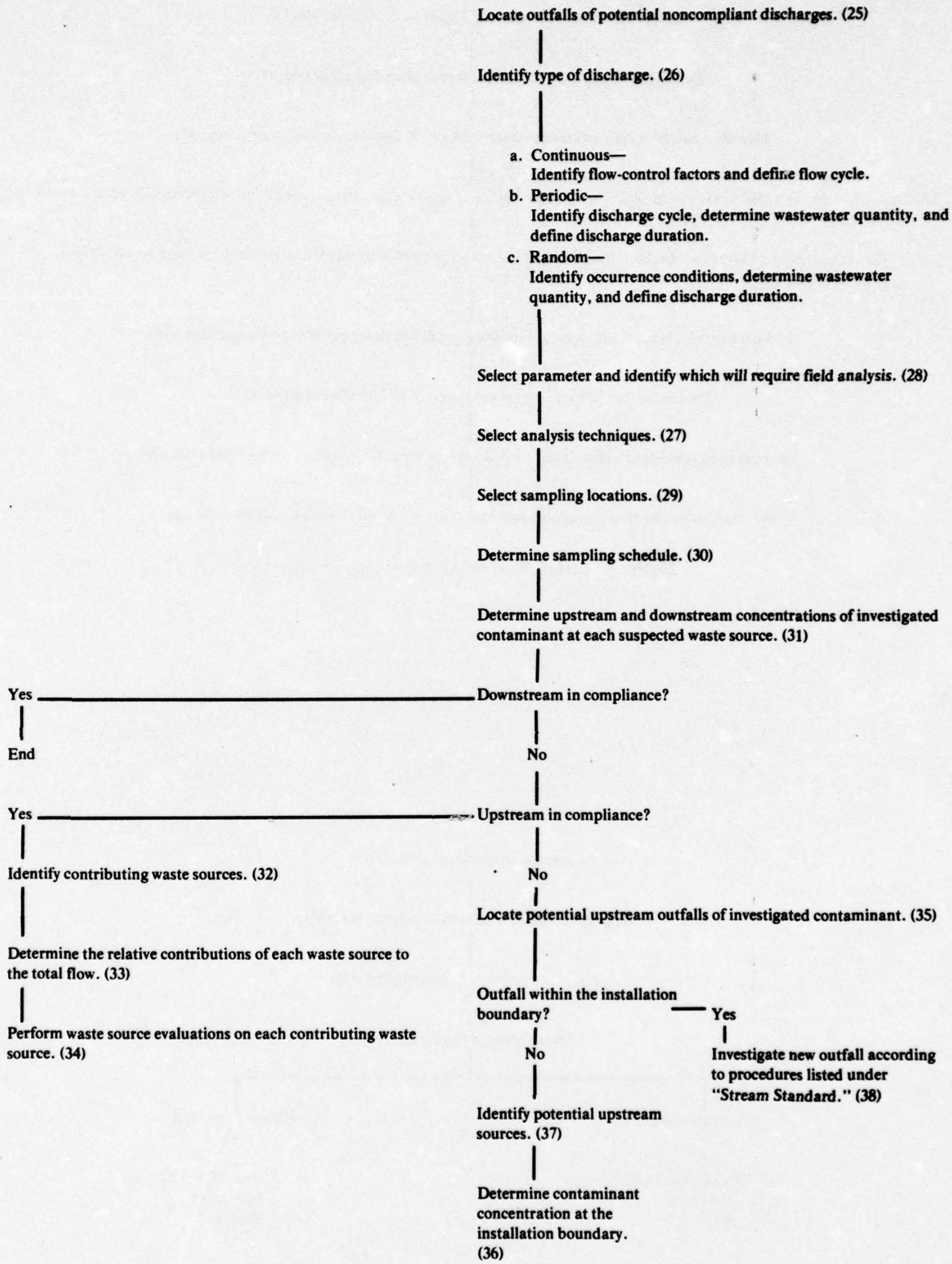

Figure 5. Stream standard compliance survey planning flow chart.

Locate potential noncompliant discharges. (39)

Identify any process size or total flow limitations contained in the regulations. (40)

Does investigated outfall fall within the scope of the regulations? —— No

End

Yes

Identify type of discharge. (26)

a. Continuous—
Identify flow control factors and define flow cycle.
b. Periodic—
Identify discharge cycle, determine wastewater quantity, and define discharge duration.
c. Random—
Identify occurrence conditions, determine wastewater quantity, and define discharge duration.

Identify parameters to be monitored and select analysis technique. (27)

Determine which parameters require field analysis. (28)

Select sampling locations. (29)

Determine sampling schedule. (30)

Identify type of effluent standard. (41)

a. Concentration—
Determine concentration range of suspected pollutant.
b. Total mass—
Determine total quantity of pollutant discharged by multiplying *the average pollutant* concentration by the total daily wastewater flow. (73)

Is the investigated outfall in compliance? —— Yes

End

No

Identify the waste sources contributing wastewater to the outfall. (32)

Determine the relative contribution of each waste source to the total outfall. (33)

Perform waste source evaluations on each contributing source for suspected contaminants. (34)

Figure 6. *Effluent standard compliance survey planning flow chart.*

Define the survey objectives. (42)

Locate waste sources to be investigated. (43)

Obtain a water supply, sewer, and storm drainage map for the installation. (44)

Identify paths of wastewater and stormwater drainage. (45)

Develop a detailed water supply and sewer map for the waste source. (46)

Define process flow within each waste source. (47)

Locate water-using processes and define consumption rates. (48)

Identify wastewater-producing processes and determine discharge types. (26,49)

a. Continuous—
   Determine flow control factors and flow cycles.
b. Periodic—
   Determine discharge cycle, total volume discharge, and duration of discharge.
c. Random—
   Identify discharge conditions, determine total volume discharged, and define duration of discharge.

Determine material consumption rates for each process and define the factors which control the rate of consumption of input materials. (50)

Locate any wastewater treatment or pretreatment processes. (50)

a. Identify contributing production processes.
b. Define treatment objective.
c. Determine process efficiency.

Prepare a material input diagram. (51)

Select indicator parameters. (52)

Obtain grab samples of investigated outfalls. (53)

Select analysis techniques. (54)

Determine which parameters require field analysis. (28)

Select sampling locations. (55)

Determine sampling schedule. (56)

Perform survey.

Prepare mass balance diagram. (57)

Identify wastewater discharges which can be reduced. (58)

Define correlations between wastewater characteristics and process parameters. (59)

Determine statistical variation in parameters. (60)

Figure 7. Waste source survey planning flow chart.

Define survey objective. (61)

Assemble and review available information concerning stream under survey. (62)

Define stream watershed. (63)

Locate tributaries. (63)

Define land use within watershed. (63)

Identify and locate points of wastewater discharge, type of wastewater, waste loading-pollutants, total flow, and occurrence conditions. (63)

Locate and quantify existing water uses. (63)

Define parameters to be monitored. (64)

Locate contributory point and nonpoint sources. (65)

Locate and typify existing sampling and stream-gauging stations. (66)

Define stream hydrologic history. (67)

Locate potential sampling points. (68)

Observe entire reach of stream. (69)

Select analysis techniques. (54)

Determine which parameters require field analysis. (28)

Select final sampling locations. (70)

Determine sampling schedule. (71)

Perform survey.

Define correlations between parameter, streamflow, and wastewater discharges. (72)

Define statistical variations in parameters. (60)

Figure 8. Ambient water quality survey planning flow chart.

FLOW CHART ANNOTATIONS

(1) Two types of information can be gathered—**background** information, which gives a general overview of the water quality situation; and **specific** information, which gives a detailed view of a particular problem.

(2) The two levels of background information are: **Regional** information, which describes water quality within the major watersheds of the area; and **Installation** information, which describes water quality within the boundaries of the installation.

(3) Problems requiring **specific** information surveys can be divided into four basic groups: regulation compliance, environmental impact analysis, problem characterization, and design analysis.

(4) Wastewater or runoff from the installation may enter major water bodies via tributaries. State regulatory agencies typically identify major water bodies within the state.

(5) Watershed boundaries should be traced on a topographic map with a scale of 1 in. = 1 mile (1 cm = 633.6 m). This type of map can be obtained from the U.S. Geological Survey (USGS) by requesting USGS 15 minute quad, 1" = 62,500".

(6) Regional or state regulatory agencies can assist in locating and characterizing major point sources. Sources should be plotted on the watershed boundary map and keyed to a summary sheet.

(7) Wastewater from nonpoint sources basically consists of runoff. Major nonpoint sources are industrial areas, urban areas, cultivated agricultural land, and large feedlot operations. Nonpoint sources are described in Chapter 5. Areas should be noted on watershed boundary map.

(8) Major water uses can be classified as domestic (drinking), industrial (by type of industry), recreational (by activity), and/or agricultural (irrigation or stock watering). Each use has certain minimum quality requirements which must be maintained. If these minimum levels are not maintained, complaints and possible legal action from downstream water users may result.

(9) Existing sampling and gauging stations are potential sources of current and/or historical water quality and flow information useful in both specific and background surveys.

(10) Periods of low flow, high flow, and stable hydrograph, including approximate magnitude of flow, should be defined. This information is useful in setting up sampling programs or identifying periods of maximum pollution potential.

(11) Many federal, interstate, state, and local agencies have some regulatory control over the region's water quality. To insure complete compliance with all pertinent regulations, it is necessary to contact the responsible agencies to obtain assistance in interpreting the regulations. It is strongly suggested that an up-to-date summary of water-related regulatory agencies be maintained at the installation.

(12) Many states and regions have specific water quality programs. The installation, as part of the region, should define its operational responsibilities within the regional program. It is suggested that the installation maintain an up-to-date summary of its role in regional water quality programs.

(13) Perennial streams and lakes are those which contain water year-round.

(14) Plot the watershed boundaries on a topographic map with a scale of 1 in. = ½ mile (1 cm = 316.8 m) (USGS 7.5 minute quad, 1" = 24,000").

(15) Major land uses should be categorized as cantonment, unimproved, and cultivated agricultural areas. Cantonment areas should be subdivided into residential (family housing and troop housing), industrial, parks, and business (including administrative and support) areas. Unimproved areas should be subdivided into grassland, forested, and field training and maneuver areas.

(16) Point source locations should be plotted on the watershed boundary map and keyed to a discharge summary sheet.

(17) Unconfined sources are described in Chapter 5. Areas should be noted on the watershed boundary map and keyed to a discharge summary sheet.

(18) Major water uses can be classified as domestic (drinking), recreational (by activity), industrial (by type of industry), and agricultural (irrigation or stock watering). Each water use presents certain minimum quality criteria which must be maintained. Degradation of water quality below the minimum quality criteria for a designated water use may result in increased water treatment costs or elimination of the water use.

(19) If possible, obtain an average annual hydrograph of weekly flows for each stream. USGS and state water resource agency stream-gauging stations can supply this information for streams that they monitor. If not possible, define periods and magnitude of low flow, high flow, and stable hydrograph.

(20) Up-to-date information source summaries should be kept on the installation for ease of reference. Such sources should include those gathering information on water, land use, troop activity, facility operation and maintenance, and industrial activity.

(21) Identify the specific regulatory agency involved in the inquiry, and specify a point of contact. This information is useful in determining the intent of the regulation as it applies to a specific occurrence.

(22) Locate the specific areas or activities to be investigated for compliance to specific regulations. In many instances, the enforcing regulatory agency will specify areas of questionable compliance.

(23) Parameter selection is governed by the activity under investigation and the controlling regulation. The enforcing regulatory agency can assist in selecting regulation governing parameters, and Chapters 3, 4, and 5 can assist in selecting activity-related parameters.

(24) The two basic types of regulations are stream standards and effluent standards. Stream standards, which specify a minimum water quality that must be maintained in the receiving water at all times, are usually keyed to water use. Effluent standards, which specify a minimum wastewater outfall quality, are keyed to type of wastewater discharged. Effluent standards are more prevalent than stream standards.

(25) Locate the exact point where noncompliant discharges enter the receiving water via pipe, lined ditch, natural ditch, or overland flow.

(26) There are three types of discharges—continuous, periodic, and random. Continuous discharges have constant though variable wastewater flow. Periodic discharges discharge wastewater in a batch according to some schedule. Random discharges discharge wastewater in an unscheduled slug. Chapter 7 provides guidance for measuring flow.

(27) Analysis techniques are usually specified by the governing regulation or regulatory agency. If not specified, an approved technique can be selected from the references listed in the Bibliography, based on parameter and expected concentration.

(28) Because of the dynamic nature of some parameters, field determination is necessary. These parameters should be identified so that the sampling schedule can be accommodated to perform the necessary determinations in the field.

(29) Sampling locations may be governed by the regulatory authority. In cases where they are not, Chapter 6 provides some guidance in selecting a sampling point in a stream.

(30) Sampling frequency, duration, and period selection may also be governed by the regulatory authority. Chapter 6 also provides guidance in these areas.

(31) Compliance concentrations and occurrence conditions are usually defined by the regulatory agency.

(32) Identify waste sources discharging the investigated contaminant into the offending outfall.

(33) On the basis of total flow of the offending outfall, determine the relative contribution of each identified waste source.

(34) Perform waste source evaluations on each contributing waste source if more information on the source and nature of contaminants is required.

(35) Information gathered in the background surveys is useful in locating additional upstream sources of the investigated contaminant.

(36) Boundary determinations may be necessary to demonstrate that the noncompliant conditions stem from activities outside the installation's control.

(37) Information gathered by the regional survey can be used to locate upstream sources that might be causing the noncompliant conditions.

(38) Repeat investigation of new outfall according to the procedures listed under "Stream Standard" of the regulation compliance survey.

(39) Locate all point and nonpoint sources generating the investigated contaminant.

(40) Some effluent standards have maximum and/or minimum limitations on the size of industrial process or the total wastewater flow generated by a waste source. These limitations tailor the regulation to the size of the operation. Regulatory agencies can supply the needed guidance in determining the applicability of the regulation.

(41) There are two types of effluent standards—concentration and total mass. Concentration effluent standards define minimum quality criteria for wastewater discharges while total mass effluent standards limit the total amount of contaminant which can be discharged over a specified time period.

(42) The basic reasons for evaluating waste sources are:

a. Location and characterization of specific process(es) responsible for noncompliant wastewater discharges
b. Location of areas amenable to water reuse or material recovery
c. Reduction of pollution levels
d. Determination of wastewater characteristics required for treatment process design
e. Determination of the correlation between pollutant loading and production levels.

(43) Identify by building number and location on a cantonment map the specific waste sources to be investigated.

(44) Water supply, sewer, and storm drainage maps are useful in determining where and how water is supplied to the investigated waste source, and where and how wastewater and stormwater are removed.

(45) Identify potential sources of dilution water, points of outfall, and any wastewater treatment.

(46) The water map is used in identifying water supply within the waste source, while the sewer map is used in defining wastewater removal systems and locating sampling points.

(47) Identify the basic sequence processes within the waste source and prepare a schematic diagram for the waste source.

(48) Using the detailed water supply map, locate processes that use water and estimate or otherwise determine their water consumption rates. Note this on the process schematic.

(49) Use the detailed sewerage map and note wastewater outfalls on the process schematic.

(50) Note this on the process schematic.

(51) Using the process schematic, determine materials and water supplied to, passed through, and discarded by each process. Identify materials entering the wastewater and estimate their concentration within the wastewater.

(52) Select wastewater parameters which will provide a measure of the suspected contaminants in the wastewater as well as those reflecting the objectives of the survey. Add to this list wastewater flow, production control, and material consumption factors. Chapters 4 and 5 supply some guidance in selecting parameters.

(53) Preliminary grab samples should be analyzed for physical, chemical, and biological indicator parameters.

(54) Depending on the parameter concentration, interfering substances, and occurrence conditions, select the appropriate

analysis technique. The Bibliography lists standard references for analysis techniques.

(55) Select suitable sampling locations from the detailed sewerage map, accordance with the objectives of the survey and the processes under investigation. Chapter 6 provides guidance in choosing a sample location.

(56) The sampling schedule is determined by the objectives of the survey, the nature of the process being investigated, and the parameters being analyzed. Chapter 6 provides guidance in formulating this schedule.

(57) Prepare the mass balance diagram across each process and across the entire waste source. Chapter 3 provides guidance in preparing a mass balance diagram.

(58) Determine which wastewater discharges can be reduced or eliminated by minor changes in "housekeeping" or operating practices.

(59) Define correlations between wastewater flow and flow control factors, pollutant concentrations and material consumption factors, wastewater flow and pollutant concentrations, and any other correlation pertinent to the survey objectives.

(60) Define the maximum, minimum, and average values of the investigated parameters as well as the standard deviation of all values and cumulative frequency of occurrence for all values.

(61) Several classes of survey objectives are encompassed in an **ambient water** quality evaluation:

a. Determination of the physical, chemical, and biological characteristics of the receiving stream

b. Assessment of the effect of a specific wastewater outfall on the receiving water

c. Determination of the suitability of a stream for a particular water use

d. Assessment of the effectiveness of current water pollution control programs.

(62) Previously gathered information is useful in developing an understanding of the stream to be investigated. Regulatory agencies are often valuable sources of unpublished information.

(63) Information gathered under the Installation Survey can be used. Information should be recorded on a topographic map with a 1 in. = ½ mile (1 cm = 316.8 m) scale (USGS 7.5 minute quad 1" = 24,000).

(64) Select water quality parameters which reflect the objectives of the survey as well as indicate levels of suspected contaminants.

(65) Locate contributory sources of chemical and biological contaminants. Define quantity, quality, and occurrence conditions of identified outfalls and record this information on the topographic map.

(66) Existing stations provide historic water quality and flow data to be used in establishing the sampling network. Record this information on the topographic map.

(67) Stream hydrologic history is used in selecting sampling periods. It is usually best to run a specific survey during periods of relatively stable hydrograph. Chapter 7 provides some guidance on flow measurement.

(68) Using the topographic map and noting the contributing point and nonpoint sources, select potential sampling stations which will reflect the objectives of the survey. Chapter 6 supplies guidance in selecting these locations.

(69) Observe the entire stream reach under investigation either by boat or on foot. Check the actual locations of outfalls, the existence of unanticipated outfalls, and the suitability of proposed sampling stations. Also collect grab samples of stream water, investigated outfalls, and unanticipated outfalls for chemical and biological analysis. These samples will be used in selecting an analytical technique.

(70) Review the suitability of preliminary sampling stations and make any required modifications. Also identify any auxiliary equipment, such as flow recording instrumentation or automatic monitoring equipment, which must be located at the sampling point.

(71) The sampling schedule is determined by the objectives of the survey, the duration of stable conditions, and the parameters being investigated. Chapter 6 provides some guidance in formulating this schedule.

(72) According to the objectives of the survey, define the correlation between monitored parameters and stream flow or wastewater discharge levels.

(73) To determine the total mass of pollutant discharged from a highly variable waste source, it may be necessary to monitor the pollutant concentrations for a period of time. Average pollutant concentration can then be determined by summing the product of concentration values and frequency of occurrence and dividing by the total number of samples according to:

$$\overline{C} = \frac{\Sigma C(n_C)}{n_T}$$

$\overline{C}$ = average pollutant concentration
C = pollutant concentration value
n_C = number of samples of concentration, C
n_T = total number of samples.

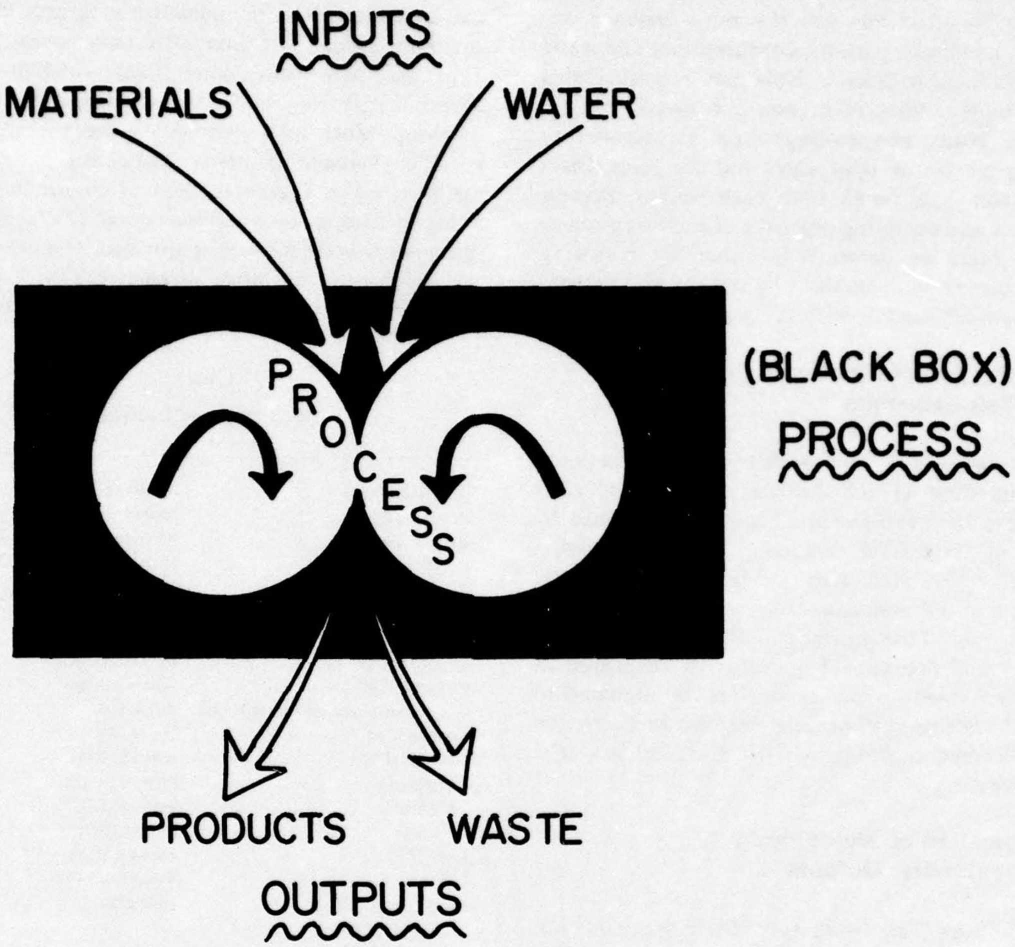

Figure 9. Simplified process system diagram.

tions by specific wastewater-producing systems. Identification of specific regulations serves to define some of the wastewater parameters to be investigated, while identification of specific wastewater sources limits the number of sources requiring investigation. Most specific wastewater investigations have regulation compliance objectives.

Problem characterization objectives are typically keyed to a specific problem occurring in a specific area under specific conditions. Identification of the problem to be investigated helps define the parameters to be studied, the specific wastewater processes creating the problem, and the conditions under which the problem occurs.

Design analysis objectives usually consist of a need for field data on the characteristics of a specific wastewater outfall in order to design a particular wastewater treatment system. These objectives are linked to specific wastewater sources and are devoted to determining the treatability of the wastewater outfalls. Depending on the extent and type of treatment desired, specific parameters to be investigated may or may not be defined.

Environmental impact analysis objectives are linked to specific projects; environmental impact assessments define wastewater outfalls that require field investigation to determine their environmental impact, and the parameters to be investigated.

Once specific survey objectives indicate the need for a wastewater source investigation, the physical

location and extent of this source must be determined. To effectively use the mass balance approach, all inputs, outputs, consumption, and waste elements must be known. This may require that a very complex source be broken into several simpler systems. Water and sewerage maps can be used to identify sources of input water and the point where wastewater is disposed from each source. Process sequence and operating practices of each wastewater source must be determined either by reviewing source operation manuals or by talking with personnel who work directly with the source.

Identification of Process Elements and Their Sequence

The mass balance approach requires a functional understanding of the process elements of each system to be investigated. This can be obtained by reviewing operation manuals and interviewing personnel who work with the investigated process. After an initial understanding has been achieved, a walking tour of the process should be taken to document actual operational practices. A schematic of the investigated system should then be prepared to show the sequence of process elements and describe each element, including what it does and how it is operated.

Identification of Water Inputs and Wastewater Outputs

Water supply and wastewater discharge points can be identified for each process element from detailed water supply and sewerage maps of the investigated system. A review of operation manuals and treatment plant records, and interviews with process operations personnel can supply information on the magnitude of water supplied and wastewater discharged, the periodicity of flow, and factors which control the flow periodicity. Since many systems operate differently in practice than in theory, actual operating and housekeeping water-use practices should also be checked during a walking tour of the system. All information on water supply, wastewater discharge, water use, and operational practices should be noted on the process schematic.

Selection of Parameters to Be Investigated

Parameters are selected on the basis of identified contaminants and survey objectives. Review of previously determined material consumption and/or contaminant introduction rates will help define major contaminating elements. Selected parameters can be either direct or indicative measures of contaminant levels. Direct-measure parameters (Table 1) are used to measure contaminants which maintain their integrity from time of introduction until time of disposal. Most such parameters are measures of specific chemical elements. Indicative parameters are used when a general class of contaminants is being measured, or when particular characteristics of the wastewater must be quantified. Contaminants measured using indicative parameters (Table 2) may or may not maintain their integrity from introduction to disposal.

Table 1

Direct Measure Parameters

Aluminum (Al)	Methane (CH_4)
Arsenic (As)	Nickel (Ni)
Barium (Ba)	Nitrogen, ammonia (NH_3-N)
Beryllium (Be)	Nitrogen, nitrate (NO_3-N)
Boron (B)	Nitrogen, nitrite (NO_2-N)
Bromide (Br^-)	Phenols
Cadmium (Cd)	Phosphorus (P)
Calcium (Ca)	Potassium (K)
Chloride (Cl^-)	Selenium (Se)
Chromium, total and +6 (Cr[+6])	Silica (Si)
Copper (Cu)	Silver (Ag)
Cyanide (CN^-)	Sodium (Na)
Fluoride (F^-)	Strontium (Sr)
Iodide (I^-)	Sulfate (SO_4^{-2})
Iron (Fe)	Sulfite (SO_3^{-2})
Lead (Pb)	Temperature
Lithium (Li)	Vanadium (V)
Magnesium (Mg)	Zinc (Zn)
Manganese (Mn)	
Mercury (Hg)	

In addition to monitorable parameters, information on certain aspects of process operation must be gathered to facilitate data interpretation. This includes the water-use and materials-use information previously gathered. Chapters 4 and 5 provide assistance in selecting monitorable and process description parameters for specific waste sources.

Performance of Water Balance

Flow-measuring devices should be installed on all identified water input and wastewater discharge points so data can be gathered on water supplied to and discharged from the system (Chapter 7). In some instances, the required number of flow-measuring devices can be reduced by estimating either water demand or wastewater production. Water demand and wastewater production can be approximated by using estimation factors (e.g., residential

Table 2

Indicative Parameters

Parameter	Indication
Acidity	Measure of capacity of water to donate protons; indicates amount of base required for neutralization. Includes weakly ionizing acids, hydrolyzing salts, and mineral acids.
Alkalinity	Measure of capacity of water to accept protons; indicates amount of acid required for neutralization. Includes bicarbonate, carbonate, and hydroxide components of water.
Carbon dioxide (CO_2)	Measure of free carbon dioxide; indicates corrosiveness of water. Cannot be mass balanced.
Chlorine, residual	Measure of amount of chlorine remaining after reaction with all oxidizable components.
Chlorine demand	Indication of the amount of chlorine-oxidizable components in the water.
Chlorine dioxide	Same as chlorine (residual).
Color	Indication of color-causing contaminants such as metallic ions, humus, peat, weeds, plankton, and industrial wastes.
Hardness	Measure of the capacity for precipitating soap; indicates polyvalent metal concentration, primarily calcium and magnesium.
Nitrogen, Albuminoid	Indication of the quantity of proteinaceous nitrogen.
Nitrogen, Ammonia (NH_3-N)	Indication of reduced nitrogen.
Nitrogen, Nitrate (NO_3-N)	Indication of oxidized nitrogen.
Nitrogen, Nitrite (NO_2-N)	Indication of intermediate stage of nitrogen cycle.
Nitrogen, Organic (Organic-N)	Indication of all biological product nitrogen.
Nitrogen, Total Kjeldahl (TKN)	Indication of organic and ammonia nitrogen.
Odor	Indication of organic and inorganic odor-producing compounds.
Oil and grease	Indication of nonmiscible organic compounds in the water.
Organic carbon, total (TOC)	Indication of organic contamination.
Organic contaminants (carbon chloroform extract [CCE])	Indication of organic compounds removed by activated carbon filter and soluble in chloroform and/or ethanol.
Oxygen, dissolved (DO)	Indication of the level of free unreacted oxygen. Cannot be mass balanced.
5-day oxygen demand, biochemical (BOD_5)	Measure of the amount of oxygen consumed in 5 days by biodegradation of organic compounds; indicates biodegradability of the waste components.
Oxygen demand, chemical (COD)	Measure of the amount of oxygen consumed by chemical oxidation of waste components; indicates the level of oxidizable waste contamination.
Ozone (residual) (O_3)	Measure of the amount of ozone remaining following reaction with all oxidizable components.
pH	Indicates the instantaneous hydrogen ion activity as a measure of the degree of acidity or alkalinity with respect to neutral (pH 7) water.
Phenols	Measure of hydroxy-derivatives of benzene.
Specific conductance (dissolved solids) (TDS)	Measure of the water's capacity to conduct current; indicates the concentration of dissolved substances.
Sulfide	Indicates anaerobic bacteriological degradation of organic wastes.
Surfactants (anionic)	Indication of synthetic detergents.
Tannin and lignin	Indication of hydroxylated aromatic compounds.
Taste	Measure of organic and inorganic taste-producing contaminants.
Turbidity	Measure of suspended matter in the water.
Solids, total (TS)	Measure of solid residue which remains after evaporation at 103-105°C.
Solids, total suspended (TSS)	Measure of solid residue which remains after evaporation of a filtered sample of water at 103-105°C.

water demand using a 400 gal/unit/day estimation factor) or by noting process water supply or wastewater discharge requirements as specified in the process operation manuals for the investigated system (e.g., an industrial laundry washing machine manual states that it uses 60 gal of water/wash cycle). When water supply is estimated, wastewater production must be measured and vice-versa. However, when there is a need for accurate data, or when there is an unaccountable discrepancy between water supply and wastewater production, flow-measuring devices on both water input and wastewater output points must be installed.

Installation of flow-measuring devices will require substantial investments in both manpower and equipment. However, because of the lack of internal metering at military facilities, installation of flow-measuring devices is required for gathering accurate flow data and developing accurate historical flow records.

Water consumed or lost by the system can be quantified by using information from process operation manuals, walking tours, and operations personnel. Water use, water supply, and wastewater discharge information should be gathered for a preselected time period that is long enough to include most of the periodic and irregular wastewater discharges typically occurring within the system. A water balance for that time period should be performed for all process elements in the system. The water supplied and consumed, and the wastewater discharged by each process element over the specified time period should be recorded.

The total water supplied to the system should be compared to the sum of water supplied to each process element in the system. If the total water supplied to the system is greater than the sum of the water supplied to the process elements, some additional water-**using** process elements have not been considered. If the total water supplied is less than the sum of process element water supplies, additional water **supply** points have not been considered.

Similarly, total wastewater discharged from the system should be compared to the sum of the wastewater discharged by each process element. If the system's total wastewater is greater than the sum of the process element discharges, some wastewater-**producing** processes have not been considered. Conversely, if the total is less than the sum of the process element discharges, additional combined **outfall** points must be considered.

Finally, the total water supplied to the system and the total water consumed must be compared to the total wastewater discharged. The difference should be relatively small; a large deviation may indicate a missing water supply point, wastewater discharge point, or water-consuming process.

Performance of Survey and Materials Balance

There are several ways to perform a materials balance, depending on the type of parameter being investigated and the nature of contaminant introduction into the wastewater. Four basic situations determine the type of materials balance performed: (1) where direct-measure parameters are investigated and contaminating materials are added to the wastewater in a metered manner; (2) where direct-measure parameters are investigated and contaminants are added in an unmetered or irregular fashion; (3) where indicator parameters are being investigated and contaminants are added in a metered fashion; and (4) where indicator parameters are being investigated and contaminants are added in an unmetered fashion.

For the first situation, input materials are balanced against output contaminants for each process element in the system. Using the common time period selected in the water balance, the mass of input materials is calculated from the previously determined consumption rate. The mass of output contaminants in the wastewater is calculated by multiplying the contaminant concentration determined by field investigation times the total wastewater discharged over that time period. Total input materials should approximately equal the sum of the materials consumed (as defined in operations manuals for the process element) and the contaminants discharged. Any great differences may result from overlooked material inputs, material-consuming processes, or wastewater outfall points. Finally, the sum of the mass of contaminants discharged from all process elements should nearly equal the mass of contaminants discharged from the entire system. Deviations may result from unconsidered process element discharges or system wastewater outfall points.

In all other situations, the first step of the materials balance is to use some sort of waste estimation factor to estimate the mass of materials put into each process element. These waste estimation factors may be based on field data or literature data. For direct measure parameters where contaminants are added

in an unmetered fashion, the factor needed to estimate input materials should relate mass of input materials to some readily quantifiable event; for example, pounds of copper sulfate added per million gallons of water treated to estimate copper and sulphate concentrations. For indicator parameters where contaminants are added in a metered manner, the waste estimation factor should translate the metered material in terms of the indicator parameter; for example, pounds BOD_5 per 1000 pounds laundry detergent to estimate BOD_5 demand of the laundry detergent used.

For the situation where indicator parameters are under investigation and contaminants are introduced in an unmetered fashion, both of the above types of waste estimation factors must be used: the amount of input material is estimated using a factor which relates the mass of input materials to some quantifiable event, while, after the amount of input material is calculated, a factor which translates the input material in terms of the indicator parameter is applied.

If the amount of input materials can be approximated, then the materials balance proceeds as described for direct measure parameters with metered contaminant addition. If the input materials cannot be estimated, then the materials balance consists of comparing the total mass of contaminants discharged from the system with the sum of the contaminants discharged from the process elements.

The following example is provided to better illustrate the mass balance concept.

Example Mass Balance

Camp Swampy decided to treat its bakery wastewater prior to discharge into Suffolk Creek. The bakery obtains 50,000 gpd (189.3 m^3/day) from the installation water treatment plant via a 4-in. (10.16 cm) main. Wastewater is removed from the bakery and transported to Suffolk Creek via an 8-in. (20.32 cm) gravity sewer.

Internally, wastewater comes from three areas—baking pan washing, raisin washing, and restroom-housekeeping activities. The bakery has 44 full-time employees split into two shifts, 2200 to 0600 hours and 0600 to 1400 hours. Figure 10 shows the process sequence within the bakery and Table 3 shows the water/wastewater balance. The raisin container and utensil baths are emptied twice daily and replaced with fresh cleaning solution. Table 4 shows the composition of various cleaning agents used in the bakery.

Table 3

Water Balance, Camp Swampy Bakery

Process	Water Supplied, gpd (m^3/day)	Wastewater Produced, gpd (m^3/day)
Raisin wash	1500 (5.7)	1500 (5.7)
Raisin rinse	7840 (29.7)	6800 (25.7)
Container wash	1000 (3.8)	1000 (3.8)
Container rinse	4780 (18.1)	4350 (16.5)
Utensil wash	6000 (22.7)	6000 (22.7)
Utensil rinse	25400 (96.1)	24240 (91.8)
Equipment cleanup	500 (1.9)	380 (1.4)
Housekeeping	140 (0.5)	85 (0.3)
Restroom/shower	920 (3.5)	880 (3.3)
Process water	2000 (7.6)	—
TOTAL	50,080 (189.6)	45,235 (171.2)

The parameters investigated included BOD to indicate biodegradable waste strength, COD to indicate oxidizable waste strength, pH to indicate alkalinity caused by the cleaning agents, and total solids. Since indicator parameters were used and material inputs could not be estimated, an exact materials balance was impossible. However, it was possible to compare the sum of the contaminants of the contributing process elements with the actual contaminants of the total output as measured at the outfall from the bakery. Table 5 shows that the actual and calculated results are nearly equal; thus a materials balance was performed.

4 CONFINED WASTE SOURCES

Figure 11 is an organizational schematic of waste source investigations. As the figure indicates, there are two types of wastewater sources—confined and unconfined (the latter are discussed in Chapter 5). Confined sources generate wastewater in a limited area and in amounts proportional to the level of human activity. Domestic sewage and industrial process water are examples of effluent from confined sources.

Confined waste sources can be divided by functional categories into industrial, institutional, utility, and domestic, with each category further subdivided according to the operations performed within it. This chapter describes the discharge from each

Table 4

Analysis of Typical Washing Compounds, Camp Swampy Bakery

Utensil Cleaner %		Container Cleaner %		General Maintenance Cleaner %	
46	Sodium carbonate	32	Sodium metasilicate	15	Sodium carbonate
33	Sodium metasilicate	22	Trisodium phosphate	15	Sodium metasilicate
4	Sodium chromate*	18	Sodium sesquicarbonate	55	Trisodium phosphate
17	Sodium thiosulphate*	13	Sodium sulphate	13	Sodium sesquicarbonate
		2	Alkyl sulphonate	2	Alkyl sulphonate**
		1	Nonionic detergent**		
		10	Ultramarine blue color		
		2	Sodium nitrite		

*Replaced with sodium nitrite where water disposal is made to groundwater.
**Biodegradable detergents.

Table 5

Results of Analysis

Location	pH	COD		BOD		Total Solids	
		mg/l	lb/day (kg/day)	mg/l	lb/day (kg/day)	mg/l	lb/day (kg/day)
Raisin wash	4.7	4272	53.54 (24.28)	3015	37.79 (20.25)	4238	53.12 (24.09)
Raisin rinse	6.5	654	37.16 (16.85)	538	30.57 (13.87)	475	26.99 (12.24)
Container wash	10.5	9400	78.54 (35.63)	8100	67.68 (30.70)	12272	102.54 (46.51)
Container rinse	9.5	1568	56.99 (25.85)	1005	36.53 (16.57)	1526	19.46 (8.83)
Utensil wash	10.5	15,520	778.06 (352.92)	8200	411.09 (186.47)	13550	679.29 (308.12)
Utensil rinse	9.7	2440	494.19 (224.16)	1210	245.07 (111.16)	1916	388.06 (176.02)
Equipment cleanup	8.7	2700	8.57 (3.89)	1310	4.16 (1.89)	4750	15.08 (6.84)
Housekeeping	8.2	12,350	8.77 (3.98)	9300	6.60 (2.99)	8470	6.02 (2.73)
Restroom/shower	7.6	424	3.12 (1.42)	286	2.10 (0.95)	350	2.57 (1.17)
Measured total	9.2	4100	1549.62 (702.90)	2320	876.86 (469.93)	3510	1326.63 (601.75)
Calculated total	9.1	4019	1518.94 (688.98)	2227	841.59 (381.74)	3421	1293.13 (586.55)

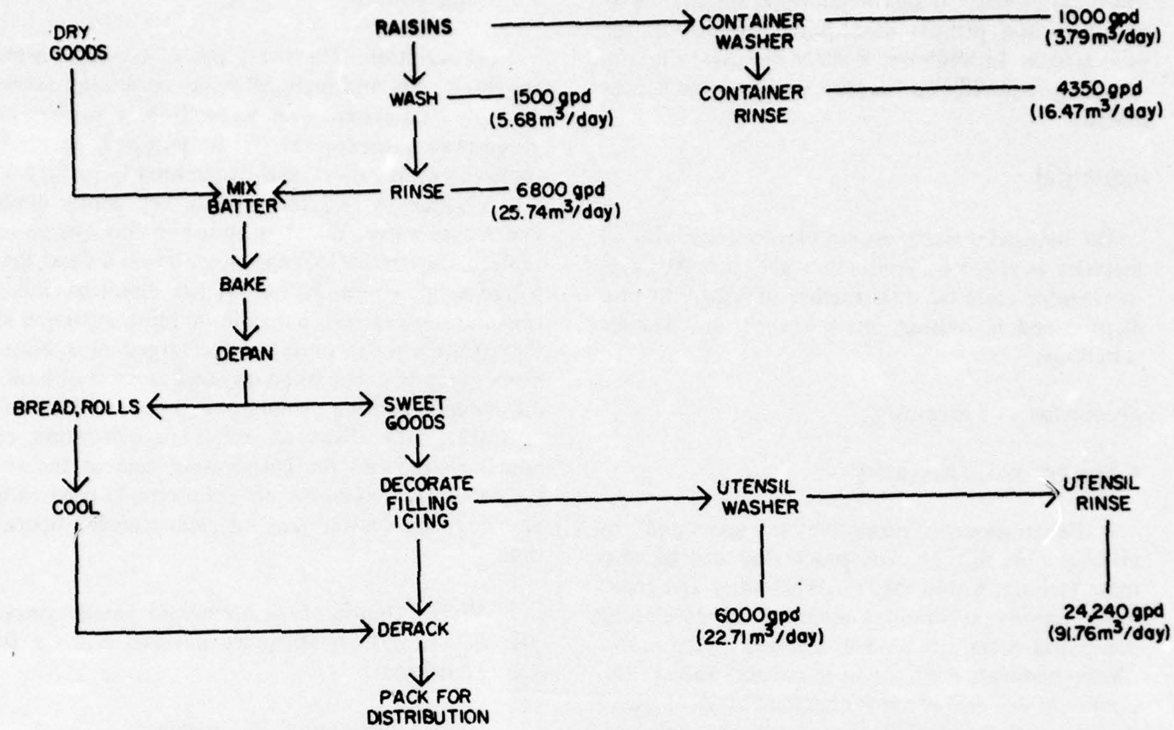

Figure 10. Bakery process sequence.

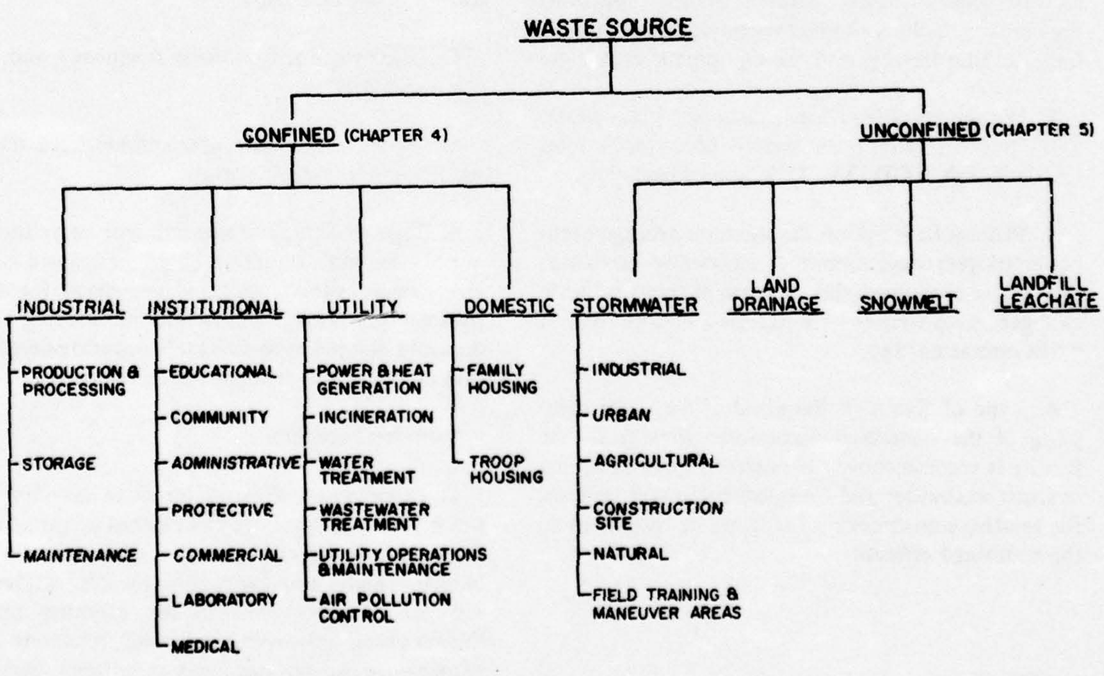

Figure 11. Organizational schematic of wastewater sources.

waste source and lists significant water quality measurements and process description parameters for each source. In addition, a short discussion of the sampling requirements for each waste source is presented.

Industrial

The industrial waste source category includes all facilities engaged in production and processing of marketable material. It is further divided into production and processing, maintenance, and storage subgroups.

Production and Processing

- Photographic Laboratory

1. Description: Wastewater is generated by photographic film or plate processing and by restroom facilities within the lab. Washwater and rinsewater remove substantial amounts of developing liquid and chemicals used in the developing baths. These chemicals are toxic to plant and animal life. Continual disposal of spent chemical baths or use of flow-through chemical baths increases the toxic concentrations of the effluent. Photo lab effluents contain large amounts of chemical-reducing contaminants, which tend to exert a high chlorine demand on wastewater or water treatment plants. Contributing facilities include the signal photographic laboratory, the film library, and the equipment exchange.

2. Water Quality Measurements: pH, BOD, TOC, NH_3-N, TKN, heavy metals (Zn, Cd, B, total Cr, Cr^{+6}, Ag), COD, TS, TSS, and phosphorus.

3. Process Description Parameters: average number employees/day, volume of washwater used/day, total water consumed/day, volume of chemical bath changed, frequency of bath changes, and number of baths operating/day.

4. Type of Sample* Required: Composite sampling of the combined wastewater flow from the facility is recommended. If possible, grab sampling of spent washwater and chemical baths will indicate the relative contribution of each wastewater type to the combined effluent.

*Chapter 6 describes the various sample types.

- Cooling Towers

1. Description: The two types of cooling towers are single-pass and high-efficiency recycling towers. A single-pass system uses water from a surface or groundwater source which is pumped, heated, cooled by evaporation, and discharged to surface or groundwater. A recycling system repeatedly cools and reuses water. Water is added to this system to replace evaporative loss and to maintain a fixed dissolved solids concentration. If the dissolved solids concentration exceeds a maximum limit, a portion of the system's water must be discharged in a blowdown operation. The frequency and amount of blowdown depend on the maximum dissolved solids concentration, the dissolved solids concentration of added water, and the evaporation rate of the recycled water. Cooling towers are normally used with any large air-conditioning or heat-transfer operation.

2. Water Quality Measurements: temperature, pH, TDS (for high efficiency towers), and Cu (if algicide is used).

3. Process Description Parameters:

In general: type and location of discharge, type of process (single pass or recycle), and type and concentration of algicide used.

Recycle systems: blowdown frequency and blowdown quantity.

Single-pass systems: water volume used/day and water temperature at outfall.

4. Type of Sample Required: For recycling cooling towers, grab sampling of the blowdown is sufficient; composite sampling is suggested for single-pass cooling tower systems. Site monitoring of temperature and pH renders a more accurate determination of the actual effluent characteristics.

- Laundry Facilities

1. Description: Wastewater from laundry facilities is generated primarily by clothes washing. Pollutants include grease, oil, and dirt removed from clothing; and soap, detergents, bleach, brighteners, and other agents used in the cleaning process. Dry-cleaning operations produce relatively small amounts of wastewater, but pollutants from dry-cleaning establishments may be introduced into the

drainage system when spent cleaning fluids are disposed or when water sprays are used to clean solvent storage containers. Restroom facilities in a laundry plant contribute a small amount of wastewater flow.

2. Water Quality Measurements: pH, TS, TSS, grease and oil, phenols (dry cleaning), ABS/LAS/surfactants, NO_3-N, phosphorus, BOD/COD, and TOC.

3. Process Description Parameters: total number of wash loads/day, total water volume used/wash load, amount of clothing cleaned, disposal practices for spent dry-cleaning solvents, frequency of solvent storage container cleaning, amount of laundering agents used/wash load, and number of employees/day.

4. Type of Sample Required: A time- or flow-composite sample of the facility outfall is recommended. Grab samples at different stages of the laundering operation aid in determining the relative contribution of each stage. Interpretation of grab-sample data requires information on relative wastewater flow.

• Food Preparation Facilities

1. Description: Facilities considered in this section include bakeries, restaurants, and mess halls. Other facilities which generate similar wastewater include hospital food service; officer's and enlisted men's clubs; snack bars; and barracks or dormitories with mess, restaurants, or cafeterias.

Wastewater produced by food preparation facilities is derived mostly from processing and preparation of food; lesser amounts are generated by restroom usage. Wastewater from bakery facilities is produced by washing of equipment and storage containers. Similarly, mess hall and restaurant wastewater is generated by cleaning of equipment and storage containers, and by disposal of waste food through garbage grinders. All of these wastewaters have high concentrations of organic carbon, settleable and/or suspended solids, and nutrients.

2. Water Quality Measurements: pH, BOD, COD, TOC, NH_3-N, TKN, phosphorus, suspended solids, settleable solids, grease and oil, and ABS/LAS/surfactants.

3. Process Description Parameters:

Bakery: volume of process water used/day, volume of equipment-cleaning water used/day, total weight of bakery goods produced/day, total weight of garbage disposed in wastewater/day, volume of water used for area cleanup, frequency of area cleanup, square footage cleaned, and amount of cleaning agents used/day.

Restaurant, mess hall: number of meals served/day, mass of garbage disposed of in wastewater/day, volume of equipment cleaning water used/day, volume of water used in area cleanup, frequency of area cleanup, square footage cleaned, and amount of cleaning agents used/day.

Restroom: average number of employees/day, and average number of people served/day.

4. Type of Sample Required: A flow-proportional composite sample at the outfall of each food preparation facility is sufficient. Grab samples from contributing operations facilitate understanding of wastewater production in such operations.

• Concrete and Asphalt Production

1. Description: Wastewater from asphalt and concrete production originates primarily from equipment washing, aggregate washing, wet dust collectors, and excess mix water. Water sprays are used to control dust and clean crushing and hauling equipment in aggregate production and concrete batch plants. Wet dust collectors are used in asphalt production to control loss of fines from aggregate dryers. Wastewater flow from restroom facilities should be considered only when production facilities are permanent.

2. Water Quality Measurements:

Rock-crushing plant: TSS, TS, and pH.

Asphalt plant: TS, TSS, COD, BOD, and TOC.

Concrete plant: pH, alkalinity, TS, and TSS.

Wet dust collector: pH, TS, TSS, COD, BOD, and TOC.

3. Process Description Parameters: type and number of dust collectors used (if wet, water volume used/day), equipment washwater volume used/day, aggregate washwater volume/day, type of waste-

water collection system used, and type of wastewater pretreatment used (if any).

4. Type of Sample Required: If wastewater flows are discharged into a central sewer network, flow or time-proportional composite samples should be taken. Grab samples should be taken from each contributing sector to get a general idea of each sector's relative contribution. A total flow estimate from each sector is needed to interpret grab-sample data. Frequent grab samples of wastewater flows which are **not** discharged into a centralized system should be taken; again, a total flow estimate is required for data interpretation.

Storage

• Liquid/Fuel Storage

1. Description: Wastewater from liquid storage facilities is produced by restroom facilities and stored liquid maintenance. Wastewater from restrooms is similar to domestic sewage. Stored liquid maintenance wastewater results from washing storage tanks and cleaning spillage. Until recently, wastewater from tanker holds was discharged directly to receiving waters during cleaning operations at berthing facilities. Current EPA guidelines specify that wastewater from tanker holds be discharged to onshore wastewater treatment plants. Other liquid storage wastewaters enter receiving waters via a drainage system.

Among the many facilities in this subgroup are aircraft and marine fueling facilities, gasoline and diesel fuel stations, various types of fuel storage facilities, lubricant and solvent storage facilities, loading docks, piers, and wharves.

2. Water Quality Measurements: pH, BOD/TOC, COD, phenols, TS, TSS, and grease and oil.

3. Process Description Parameters: number of employees/day, frequency of storage vessel maintenance, quantity of water used/cleanup operation, method of wastewater disposal, type of wastewater pretreatment (if any), method of spill cleanup, volume of water used/spill cleanup, type of liquid stored, and volume of storage vessel.

4. Type of Sample Required: Because wastewater production from spill cleanup or vessel maintenance operations is irregular, multiple grab sampling is recommended. Flow- or time-proportional composite sampling of a centralized outfall is warranted if maintenance wastewater dumping is noted.

• Dry Storage

1. Description: Dry storage wastewater is generated largely by restroom and other comfort facilities for support personnel. Occasionally, large volumes of water are used to clean storage areas, but this represents only a small fraction of the total discharged to the drainage system.

Facilities producing this wastewater are shipping and receiving buildings, warehouses and depots, weapons and ammunition magazines, general storage buildings, storage sheds, salvage and surplus property facilities, and other similar facilities.

2. Water Quality Measurements: BOD, TOC, TS, TSS, and pH.

3. Process Description Parameters: number of employees/day, frequency of wet cleanup, and volume of water used/cleanup.

4. Type of Sample Required: Because wastewater flows are extremely low, a grab-sampling program is sufficient to typify such wastewaters.

Maintenance

• Vehicular Maintenance

1. Description: Wastewater from this subgroup is caused by maintenance and repair operations on aircraft, land vehicles, and sea vehicles. These operations include washing; lubrication; hydraulic system maintenance; and engine, body, and chassis repair. Most maintenance wastewater is produced by vehicle washing. Pollutants entering the drainage system include detergents, grease, oil, and dirt.

Hydraulic system (brakes, transmission, actuators, etc.) maintenance and lubrication operations (greasing and oil changes) create spent fluids and washwater which are discharged into the drainage system. Receiving waters become contaminated when spent oil or hydraulic fluids are accidentally dumped into sewers or drainage ditches. Use of water sprays for maintenance area cleanup and rinsing of empty oil and grease containers also contributes pollutants to the wastewater flow.

Engine and body repair commonly require

solvents to degrease parts, strip paint, and thin paint. When these solvents are inadvertently spilled into drainage systems, contamination of wastewater increases. Accidental or intentional dumping of radiator antifreeze or battery acid can add considerable amounts of pollutants to wastewater flow.

Potential contributing facilities include aircraft maintenance operations (hangar and field operations), mobile land vehicular maintenance operations, washracks, and service exchange facilities. Paint spray booths that use wet scrubbers to remove paint aerosols from exhaust gases introduce organic compounds into the wastewater flow. In addition, facility restrooms produce a nominal amount of wastewater.

2. Water Quality Measurements:

In general: pH, BOD, TOC, COD, TS, and TSS.

Washing operations: alkalinity, phosphorus, surfactants, grease and oils, and heavy metals (Cd, Pb, Zn, Cr).

Solvent stripping, lubrication, hydraulic repair: grease and oil, heavy metals (Cd), and phenols.

Paint and paint stripping: grease and oils, phenols, and heavy metals (total Cr, Cr^{+6}, Cd, Pb).

3. Process Description Parameters:

Washing operations: number of vehicles processed/day, amount and type of cleaning agent used/vehicle, and amount of water used/vehicle.

Solvent stripping, hydraulic repair, lubrication: disposal method for spent fluid (if not recycled), volume of liquid disposed/vehicle type, number of vehicle type processed/day, volume of solvent disposed/bath change, and frequency of bath change.

Cleanup (if water spray is used): frequency of cleanup, volume of water/cleanup, area (sq ft) cleaned, and amount of detergent used/cleanup.

Painting and paint stripping: disposal method of paint wastes, volume of waste pit (if holding pit is used), frequency of pit discharge, volume of water used/paint spray period, and average number of paint spray periods/day.

Restroom facilities: number of employees/day.

4. Type of Sample Required: Composite sampling is recommended for mixed wastewater flows from a facility; grab sampling is satisfactory for each contributing operation.

• Other Maintenance

1. Description: Wastewater is produced by restrooms, hydraulic system maintenance, lubrication procedures, and maintenance area cleanup. Restroom wastewater contains certain typical domestic contaminants; wastewater from cleaning operations contains pollutants from cleaning maintenance area spills.

Contributing facilities include: guided missile facilities, weapons and arms repair shops, electronics and electrical maintenance shops, metal and woodworking shops, general-purpose maintenance shops, battery shops, and facility engineering maintenance shops.

2. Water Quality Measurements:

In general: pH, BOD, COD, TOC, TS, and TSS.

Detergent (from cleanup): surfactants, phosphorus, and alkalinity.

Cleanup and disposal of solvents, grease, oil, and hydraulic fluid: grease, oil, and phenols.

Metal-turning cleanup: heavy metals (Zn, Pb, Cd, Ni, Ag, Fe, Cu).

Electrolyte disposal: acidity and heavy metals (Pb, Cd).

Explosives cleanup: heavy metals (Hg, total Cr, Cr^{+6}, Zn).

Rocket fuel cleanup: phenols, grease and oils, and heavy metals (Ni, total Cr, Cr^{+6}).

Welding washwater: heavy metals (Zn, Pb, Cd) and acidity.

3. Process Description Parameters:

Domestic sewage: number of employees/day and total volume of water used/day.

Cleaning operations (if washwater used): amount and type of detergent used/cleanup, volume of water

used/cleanup, square footage cleaned, and frequency of cleanup.

Spent liquid disposal (if dumped into drain system): volume of liquid disposed/disposal period, volume of water used for dilution (if any)/disposal period, frequency of disposal, and type and number of units processed/disposal period.

4. Type of Sample Required: Several grab samples from facility wastewater-producing actions are sufficient; composite samples should be taken at facility outfall point(s).

Institutional

The institutional waste source category includes all facilities involved in supplying services to the installation community and in routine operation of the installation. This category is further divided into educational, community, administrative, protective, commercial, laboratory, and medical facilities.

Educational Facilities

1. Description: Wastewater from educational buildings is predominantly restroom and maintenance washwaters. Additional wastewater sources are cafeterias and locker rooms having showers. This category includes all buildings used for education of dependents or classroom instruction of installation personnel, such as dependent schools (all grade levels), military training and instruction facilities, National Guard Armory, training aids centers, and indoor firing ranges.

2. Water Quality Measurements: TOC, BOD, COD, TSS/TS, phosphorus, NH_3-N, and TKN.

3. Process Description Parameters: number of students/day, frequency of wet cleanup, volume of washwater/cleanup, number of shower stalls, amount of detergent used/cleanup, and square footage of cleanup area.

4. Type of Samples Required: Since wastewater production is intermittent, a time-composite sampling program of building effluent is recommended. Grab samples can be used to gain further information about the contributions of individual waste-producing activities.

Community

- Community Facilities

1. Description: Wastewater from community buildings is predominantly restroom and washwater flows; however, the infrequent use of these facilities results in irregular wastewater production. Wastewater is also produced by shower facilities in physical education facilities and gymnasiums.

Among the many community facilities contributing to the wastewater flow are general-purpose auditoriums, bus stations, post and unit chapels, physical fitness centers, community centers, golf clubhouses, library facilities, all sports and recreation facilities, youth and day care centers, Red Cross buildings, and museums.

2. Water Quality Measurements: TOC, BOD, COD, TSS/TS, phosphorus, NH_3-N, and TKN.

3. Process Description Parameters: number of building users/week, frequency and duration of use/week, number of shower stalls, frequency of cleanup, volume of cleanup water used/cleaning, square footage of cleanup area, and amount of detergent used/cleanup.

4. Type of Sample Required: Since community facilities are used intermittently, a grab-sampling program is sufficient. Samples should be obtained during usage periods.

- Swimming Pools

1. Description: The nature and quantity of wastewater discharged from swimming pools depends on the size and type of pool. There are three basic varieties of pools: recirculating, fill and draw, and flow-through.

The recirculating pool (the most common type) recycles water by filtration and chlorination. Wastewater is produced by filter backwash, pool overflow, and periodic cleaning of the pool and related equipment.

The fill and draw pool is initially filled with fresh water, used for some time, emptied, cleaned, and refilled. This type of pool is generally prohibited for

health reasons. If such a pool exists, its wastewater consists of the emptied pool water and washwaters.

The flow-through pool is continuously filled with fresh water, with the overflow being disposed through the drainage system. The water volume in the pool is more or less displaced daily, depending on the number of bathers. The pool is completely drained and cleaned periodically; this generates the majority of wastewater flow.

Shower and restroom facilities also contribute to the total wastewater flow.

2. Water Quality Measurements: BOD, temperature, TOC, COD, pH, TS/TSS, residual chlorine, and Cu.

3. Process Description Parameters:

In general: number of shower stalls, pool type, pool volume, volume of washwater used/pool cleaning, amount of detergent used/cleaning, frequency of cleaning, and number of bathers/day.

Recirculating pools: frequency of filter backwashing, backwash volume, and chemical additives and concentrations.

Fill and draw: frequency of water replacement.

Flow-through pools: rate of flow (pool retention time).

4. Type of Sampling Required: A time-composite sampling program is recommended for flow-through pools. Discharges from recirculating pools, fill and draw pools, and filter backwash can best be characterized by a grab-sampling program during peak discharge periods.

Administrative Facilities

1. Description: Wastewater from administrative buildings consists of restroom flow and cleaning water. The wastewater flow is very irregular and peaks at midmorning, noon, and midafternoon.

Contributing facilities include various types of communications facilities, commercial facilities, flight control towers, radar installations, shipping and receiving facilities, various command-level headquarters buildings, post offices, and office spaces.

2. Water Quality Measurements: BOD, TOC, TSS, NH_3-N, TKN, COD, TS, and phosphorus.

3. Process Description Parameters: number of employees/day, volume of cleanup water used/cleanup, frequency of cleanup, square footage of area cleaned, and amount of detergent used/cleanup.

4. Type of Sample Required: Due to the intermittent nature of the wastewater flow, a multiple grab-sampling program or automatic samplers capable of gathering multiple time-discrete samples are acceptable.

Protective Facilities

1. Description: Wastewater produced by these facilities includes restroom, shower, and cleaning waters. Since these facilities are operational 24 hr/day, they do not exhibit a typical administrative or domestic wastewater production cycle. Protective facilities include those providing police and fire protection, and criminal detention.

2. Water Quality Measurements: BOD, TOC, COD, TS/TSS, NH_3-N, TKN, and phosphorus.

3. Process Description Parameters: number of building occupants/day, frequency of cleanup, amount of detergent used/cleanup, volume of water used/cleanup, square footage of area cleaned, number of shower stalls, number of work shifts, and number of employees/shift.

4. Type of Sample Required: Although grab samples can be used to examine contributing activities, time-composite sampling is recommended.

Commercial Facilities

1. Description: Wastewater from commercial facilities is derived mainly from cleaning and restroom use. Restroom use introduces typical organic material into receiving waters; cleaning introduces waxes, grease, dirt, and cleaning solvents into the waste flow. Daily wastewater production at these facilities is usually minute, due to temporary occupancy of customers and a small number of employees.

Banks, bowling centers, retail stores (exchange), and commissaries are facilities which contribute to the overall wastewater flow.

2. Water Quality Measurements: pH, TS/TSS, phosphorus, NH_3-N, TKN, BOD, COD, and TOC.

3. Process Description Parameters: number of customers/day, daily sales volume, number of employees/day, frequency of cleanup, square footage of area cleaned, volume of water used/cleanup, amount of detergent used/cleanup, and total daily wastewater flow.

4. Type of Sample Required: Due to the extremely low flows and irregular periods of wastewater production, a time-composite sampling program is recommended. Grab samples can be used to evaluate specific activities or abnormal conditions.

Laboratories

• Mechanical Testing Laboratories

1. Description: Wastewater from these facilities is generated from restroom use, maintenance actions, and possibly from indirect introduction into the waste stream of pollutants generated by material testing. Restrooms produce organic solids; maintenance actions produce solids and oils; and testing procedures introduce chemicals, solids, and oils into wastewater.

Such facilities include various equipment facilities, physics laboratories, machine shops, general-purpose laboratory and test buildings, and vibration test laboratories.

2. Water Quality Measurements: pH, TS/TSS, oils and grease, NH_3-N, TKN, COD, BOD, TOC, and phosphorus.

3. Process Description Parameters: number of occupants/day, square footage of laboratory space, type of water usage/day, frequency of cleanup, volume of water used/cleanup, amount of detergent used/cleanup, types and amounts of chemicals used, and waste chemical disposal (frequency and method).

4. Type of Sample Required: A time-composite sampling program is recommended for the combined effluent from mechanical testing facilities. Wastewaters from individual activities can be evaluated by grab samples.

• Chemical and Metallurgical Laboratories

1. Description: Spent-chemical disposal, restroom use, and cleaning actions generate wastewater in chemical and metallurgical laboratories. Disposed chemicals contain any pollutant and exhibit any pH value. The wastewater may have a high COD and low BOD, depending on the types of chemicals disposed. Restroom use and cleaning operations introduce organic and inorganic solids into the wastewater flow. In general, wastewaters from restroom cleaning activities are high in BOD.

2. Water Quality Measurements:

In general: pH, TS/TSS, TOC, BOD, COD, TKN, NH_3-N, and phosphorus.

For disposal of metallic solutions: Hg, Pb, Ag, Cr, Cu, and Ni.

3. Process Description Parameters: square footage of area cleaned, number of occupants/day, amount of detergent used/cleanup, frequency of cleanup, water used/cleanup, quantity of metallic solution disposed/disposal period, frequency of disposal periods, and concentration of metallic solution disposed.

4. Type of Sampling Required: A time-composite or time-related grab-sampling program is recommended. Grab samples of peak wastewater flows can be used to evaluate the relative contributions of individual activities.

Medical Facilities

1. Description: Raw wastewater from medical facilities may contain toxic or pathogenic contaminants. Toxic materials are introduced into wastewater flows by disposal of spent chemicals, drugs, or disinfectants. Many drugs contain heavy metals which may be chemically transformed in the wastewater, resulting in toxic by-products. Pathogenic contaminants originate from the wastes of diseased patients. Although pathogenic waste materials are normally transformed into inert ash by incineration, if these disease-producing waste materials are passed into the drainage system untreated, persons using or having contact with the receiving water could potentially contract typhoid fever, paratyphoid fever,

dysentery, hepatitis, or other debilitating diseases.

Hospitals, medical laboratories, morgues, dental clinics, and dispensaries are facilities discharging such waste materials.

2. Water Quality Measurements: TS/TSS, coliform bacteria, phosphorus, heavy metals (Hg, Cu, Ag, Ni, total Cr, Cr^{+6}, Zn), TOC, BOD, COD, NH_3-N, and TKN.

3. Process Description Parameters: disposal method for pathogenic wastes, spent chemicals, and excess drugs, number of patients/day, quantity and frequency of disposal of disinfecting solutions, total wastewater flow/day, frequency of area cleanup, total wastewater produced/cleanup, amount of detergent used/cleanup, and square footage of area cleaned.

4. Type of Sample Required: A time-composite sampling program is recommended. Grab samples at peak flow times can be used to evaluate specific waste components or dynamic contaminants.

Utility

This category includes all facilities providing support services for the installation, such as power and heat generation, waste material incineration, water treatment, and wastewater treatment. Nonsupport service activities that use air pollution control equipment are included in this category.

Power and Heat Generation—Boiler Blowdown

1. Description: Blowdown is the periodic discharge of contaminated water from a boiler system which occurs when the boiler system water exceeds a predetermined total dissolved solids (TDS) concentration. The TDS concentration is maintained at a normal operating level when boiler water with a high TDS concentration is flushed from the boiler system and replaced with fresh water.

The amount of blowdown is directly controlled by the TDS concentration of the individual boiler system. Blowdown frequency is related to the TDS concentration of the fresh water supply and the evaporative losses in the boiler system.

Additional wastewater pollutants are introduced as inhibiting agents or for water supply pretreatment. Inhibiting agents include algicides and corrosion preventive chemicals. Pretreatment provides pH adjustment, water softening, demineralization, and solids removal.

Facilities that use boilers include: gas-, coal-, or oil-fired electric power and heating plants, nonindustrial steam power plants, and certain types of heating and air-conditioning plants.

2. Water Quality Measurements:

In general: pH, DO, TDS, alkalinity, hardness, temperature, color, and phosphorus.

For corrosion inhibitor usage: heavy metals (Cr).

For algae inhibitor usage: heavy metals (Cu).

3. Process Description Parameters: inhibitors used (with concentrations), boiler water pretreatment practices and chemical additives, blowdown frequency, and water volume/blowdown.

If blowdown frequency and water volume/blowdown are obtainable, use the following: blowdown TDS concentration, restart TDS concentration, raw water TDS concentration, water volume in the system, and evaporative losses from system.

4. Type of Sample Required: Several grab samples should be taken during a series of blowdowns.

Incinerators

1. Description: Large volumes of water are required to cool ash and residue materials prior to maintenance or cleaning of large incinerators. This cooling water is contaminated by residue and ash material.

2. Water Quality Measurements: pH, temperature, heavy metals (Pb, Cr, Zn, Cu, Ag, Cd, Ni), TS/TSS, and phosphorus.

3. Process Description Parameters: frequency of ash or residue quench, volume of quench water used, incinerator capacity, and wastewater treatment.

4. Type of Sample Required: Since quench water discharge is somewhat irregular, a grab-sampling program is recommended.

Water Treatment Plants

1. Description: Water treatment plants generate wastewater by pressure filter backwash, ion-exchange (softener) backwash, or coagulated floc disposal. Filter backwash is required periodically due to filter media contamination and head loss. Flow is reversed through the filtering media for a predetermined time and then discharged.

Ion-exchange resins are recharged whenever breakpoint effluent hardness is reached. The zeolite (softening media) is recharged by backwashing it with a concentrated brine solution which replaces Mg^{++}, Ca^{++}, and Fe^{++} with Na^{+}. When the resin has been recharged, the brine solution is discharged.

Flocculation tanks produce a waste sludge containing suspended solids and chemicals. Suspended solids are removed by coagulation, flocculation, and sedimentation. The waste sludge is either discharged, lagooned, or landfilled after dewatering.

2. Water Quality Measurements:

In general: heavy metals (As, Ba, Cd, Cr^{+6}, CN, Cu, Pb, Se, Ag), when necessary.

Filter backwash: TS/TSS, BOD, TOC, and COD.

Ion-exchange (softener) backwash: TDS (salinity), TS/TSS, and pH.

Flocculation sludge: pH, TS/TSS, phosphorus, BOD, TOC, and COD.

3. Process Description Parameters:

In general: employees/day, frequency of plant cleanup, volume of wastewater/cleanup, square footage of cleaned area, and amount of detergent used/cleanup.

Pressure filters: filter backwash frequency, backwash volume, plant size, raw water quality (TS/TSS), and heavy metals (if necessary).

Ion-exchange resins: backwash frequency, backwash volume, concentration of brine solution, plant size, and raw water quality (hardness).

Flocculation sludge: sludge volume removed/day, raw water quality (TS/TSS), plant size, and dosage of flocculating agent used/day.

4. Type of Sample Required: Since these discharges are intermittent and irregular, a grab-sampling program is recommended.

Wastewater Treatment

• Sewage Treatment Plant

1. Description: Wastewater received by a sewage treatment plant is processed to remove solids and biodegradable material before discharge into a receiving water. This effluent is often chlorinated; however, in certain situations, particularly in areas having combined stormwater-wastewater sewers, passing untreated influent directly to receiving waters is necessary.

A typical TRADOC or FORSCOM installation maintains a sewage treatment plant which receives domestic, industrial, and/or storm wastewaters. Typical plant processes include primary sedimentation, trickling filter, secondary clarification, and effluent chlorination.

Sewage treatment plants produce some wastewater through restroom usage and routine cleaning operations.

2. Water Quality Measurements:

Influent and effluent: TS/TSS, pH, phosphorus, BOD, TOC, COD, NH_3-N, and TKN.

Effluent only: DO and residual Cl.

3. Process Description Parameters: number of employees/day, frequency of cleanup, amount of detergent used/cleanup, volume of water/cleanup, square footage of area cleaned, total flow/day, separate or combined sewers, dry or wet weather infiltration rates, size and type of treatment plant, and wastewater sources (i.e., domestic, industrial, storm).

4. Type of Sample Required: A flow-composite sample is recommended for evaluating sewage treatment plant effluent; grab samples may be used to examine influent properties and dynamic parameters.

• Lagoon Discharge

1. Description: Stabilization basins or lagoons are used both for improving the quality of the effluent

from biological treatment, and for primary treatment of wastewater having a high organic content. Because of the large amount of land area required, lagoons are used primarily by industrial operations.

The two basic types of stabilization basins are the impounding-absorption lagoon and flow-through lagoon. Impounding-absorption lagoons have virtually no discharge except from excessive stormwater influx. Flow-through lagoons have a designed retention time and discharge continually. There are four types of flow-through lagoons—aerobic algae ponds, facultative ponds, anaerobic ponds, and aerated lagoons. Aerobic algae ponds use bacteria to decompose biodegradable organic waste and algal photosynthesis to supply oxygen. Facultative ponds decompose organic wastes in an anaerobic bottom layer and oxidize decomposition gases in an aerobic surface layer. Anaerobic ponds use bacteria to decompose waste materials under anaerobic conditions. Aerated lagoons use mechanical aerators to supply additional oxygen for aerobic decomposition of wastes.

Lagoons are commonly used to treat stormwater, cyanide wastes, sulfide wastes, solvent wastes, and ammonia wastes. They are also used to pretreat sewage treatment plant influent and to posttreat sewage treatment plant effluent.

2. Water Quality Measurements: BOD, TOC, COD, DO, pH, NH_3-N, TSS, and phosphorus.

3. Process Description Parameters: type of lagoon, volume of discharge, frequency of discharge, size of lagoon, degree of treatment vs. retention time, and frequency of algae and sludge withdrawal.

4. Type of Sample Required: For flow-through lagoons, a flow-proportional composite sampling program is recommended; for impounding absorption lagoons, grab sampling during discharge is recommended. Grab samples can also be used to gather information about dynamic parameters. If a lagoon is designed to remove a specific contaminant (e.g., cyanide or heavy metals), the contaminant concentration should be monitored at the outfall.

Utility Operations and Maintenance Activities

1. Description: This category includes all wastewater produced by plant personnel during operation and maintenance activities of power plants, incinerators, water treatment plants, and wastewater treatment plants. Wastewater flow is produced by restroom use, shower facilities, and cleaning water. The characteristics of this wastewater closely resemble those of wastewater produced by the institutional category.

2. Water Quality Measurements: BOD, TOC, COD, TS/TSS, phosphorus, NH_3-N, and TKN.

3. Process Description Parameters: total wastewater flow/day, number of building occupants/day, frequency of building cleanup, volume of water used/cleanup, total building area (sq ft), and amount of detergent used/cleanup.

4. Type of Sample Required: Due to the irregularity of wastewater generation, a time-composite sampling program is recommended. Grab samples can be used to evaluate source contributions and to gather information about dynamic parameters.

Air Pollution Control—Wet Collection Devices

1. Description: All air pollution control devices using water as a collecting medium are included in this category. Wet collection devices are used to control corrosive gases, aerosols such as mists and hydroscopic particulates, and gumming residues occurring in mist or particulate form. Wastewater contains contaminants cleaned from the surface of the collection device and those collected by water sprays. Wet collection devices included in this category are: spray chambers, cyclone scrubbers, orifice scrubbers, mechanical scrubbers, mechanical-centrifugal scrubbers, high pressure scrubbers, venturi scrubbers, packed towers, and wet filters.

2. Water Quality Measurements: TSS, pH, temperature, TDS, and DO.

If a device is designed to remove a specific contaminant, the level of that contaminant should be measured in the wastewater (e.g., NH_3, CN^-, heavy metals, etc.).

3. Process Description Parameters: type of wet collection device, processed air volume/day, volume of water used/day, recirculation practices employed, influent air stream characteristics, efficiency of collection device, type of wastewater discharge (continuous or slug), and type of wastewater treatment.

4. Type of Sample Required: A time-proportional composite sampling program is recommended for

continuous discharge operations; a grab-sampling program should be used for slug discharge or dynamic parameter evaluation.

Domestic

Included in this category are all facilities that house installation personnel, including single and duplex-style family housing and barracks housing troops.

Wastewater from domestic facilities is composed mainly of sanitary and cleaning wastes. Family housing wastewaters can also contain waste from laundries and garbage grinders.

Family Housing

1. Description: Waste sources include all facilities used to house military personnel and their dependents. Wastewater-producing activities include garbage grinding, laundering, dishwashing, bathroom use, and personal hygiene.

2. Water Quality Measurements: BOD, TOC, COD, phosphorus, TS/TSS, NH_3-N, TKN, and grease.

If automatic dishwashers or clothes washers are used: alkalinity, pH, and surfactants.

3. Process Description Parameters: waste flow characteristics (flow magnitude and periodicity), number of occupants, and existence of and use frequency of: garbage grinder, washing machine, and dishwasher.

4. Type of Sample Required: Due to the irregular generation of wastewater from housing, time-composite sampling program is best. A grab sample can be used to evaluate the general characteristics of individual waste streams.

Troop Housing

1. Description: Troop housing includes all permanent or transient quarters for installation personnel, except family housing. These facilities include barracks with and without attached mess facilities. Wastewater is produced from personal hygiene, bathroom use, and food preparation in quarters where mess facilities are available.

2. Water Quality Measurements: TS/TSS, TOC, BOD, phosphorus, NH_3-N, TKN, and COD.

For automatic dishwashers: pH and surfactants.

3. Process Description Parameters: number of occupants/day.

For attached mess facilities: number of meals served, size, number and use frequency of automatic dishwashing machines, and garbage disposal practices.

4. Type of Sample Required: Due to the irregular nature of wastewater generation time-composite sampling of troop housing effluent is recommended. Grab samples can be used to evaluate specific waste-producing operations.

5 UNCONFINED WASTE SOURCES

Unconfined waste sources generate wastewater over a virtually unrestricted area. Wastewater flows from these sources depend on natural phenomena rather than human activity. Stormwater and runoff are terms often used to identify wastewater flow from unconfined sources.

Unconfined waste sources are divided into four categories based on the natural sources of the wastewater: stormwater, land drainage, snowmelt, and landfill leachate. The stormwater category is subdivided according to land use (Figure 11).

Stormwater

The subsequent discussion provides guidance for understanding and typifying unconfined wastewater flows. A description of the wastewater and water quality measurements and a listing of significant parameters for typifying the wastewater are provided.

The term stormwater encompasses all wastewater produced as a result of rainfall. Since flow and pollutant characteristics of the wastewater vary according to land use, this category has been divided into industrial, urban, agricultural, construction, field training, and natural land-use areas.

Areas of 10 acres (40 469 m^2) or more with consistent land use are considered to be separate, unconfined wastewater sources. Mixed land-use areas are considered in the category of the predominating land use.

Industrial Area Runoff

1. Description: Industrial stormwater consists of runoff from production and storage areas. Production areas include all physical plants, outdoor operations such as vehicle maintenance areas, sludge-drying beds, and evaporation ponds. Storage areas include all warehouse areas and open storage areas.

Runoff can acquire heavy concentrations of contaminants as it flows across outdoor operational and open storage areas: vehicle maintenance areas and washracks add oil and grease; overflow from evaporation ponds can contribute toxic materials such as heavy metals or cyanides; sludge-drying beds contribute bacteria, organic material, and chemicals; and open storage areas containing uncovered piles of road salt can introduce dissolved solids.

2. Water Quality Measurements: pH, TS/TSS/TDS, TOC, BOD, and COD.

Maintenance areas: oils and phenols.

Plating lagoons: heavy metals (Cd, Cr, Ni).

Sludge-drying beds: fecal coliforms.

Road salt storage areas: specific conductance, Cl^-.

3. Process Description Parameters: rainfall intensity, rainfall amount, duration of continuous rainfall, soil moisture condition, area (acres) of industrial space, and runoff volume.

4. Type of Sample Required: Due to the intermittent nature of runoff, a grab-sampling program at outfalls is recommended. These samples should be taken only during or immediately following a rainstorm.

Urban (Cantonment) Area Runoff

1. Description: This category includes all runoff from the cantonment area except from those areas described under *Industrial Areas.* This runoff is usually collected by storm drainage networks and discharged into nearby receiving waters. When a combined sewer system* is used, stormwater is routed to the sewage treatment plant and either lagooned for later treatment or bypassed.

*A system that carries both stormwater and sanitary sewage.

Since the amount of runoff varies greatly according to topography, land cover, and land use, volume calculation requires dividing the cantonment area into four sectors: (1) residential areas located on flat or gently rolling terrain; (2) residential areas located on moderately steep terrain, or where housing consists of barracks/apartments (10 or more units per building complex); (3) all business or commercial areas; and (4) open areas, such as parks, school grounds, parade grounds, or golf courses.

2. Water Quality Measurements: BOD, TOC, COD, TS/TSS, pH, and conductivity (TDS).

3. Process Description Parameters: area (acres) of land use categories, soil moisture condition, rainfall intensity, rainfall amount, duration of continuous rainfall, combined/separate sewer system collection, lagooned or bypassed stormwater flows, and volume of runoff/land-use category.

4. Type of Sample Required: Grab sampling during or immediately following a rainfall is recommended.

Agricultural Area Runoff

1. Description: Agricultural runoff is generated from out-leased lands used for crop cultivation and/or feedlot operations. (Runoff from grazing land is considered in the *Natural Area Runoff* section.)

Crop cultivation introduces sediment, pesticides, and fertilizers into the runoff. Sediment contamination is greatest immediately after fall and spring plowing. Pesticide and fertilizer contamination is highest after application, usually during the late spring. Runoff volumes from cropland are calculated according to vegetative cover and terrain.

Feedlot operations, which are measured and investigated separately, introduce organic materials, solids, nitrates, and phosphates into the wastewater. Since most feedlots operate continuously, runoff is significant during the entire year.

2. Water Quality Measurements: BOD, TOC, COD, TS/TSS, and phosphorus.

For croplands: NH_3-N, TKN, and pesticide/herbicide level.

For feedlots: Organic N.

3. Process Description Parameters: type and concentration of pesticide/herbicide applied, area (acres) of land-use category, soil condition, rainfall intensity, rainfall amount, duration of continuous rainfall, and volume of runoff.

For cropland: flat or rolling terrain and time of year.

4. Type of Sample Required: Due to the random occurrence of rainfall, grab sampling should be used to evaluate agricultural runoff during or immediately following a rainstorm.

Natural Area Runoff

1. Description: Natural areas are those which are undeveloped or used for recreational activities. Depending on the area's level of development, drainage is either uncontrolled, or controlled by a network of drainage ditches.

Runoff from natural areas introduces primarily organic material and suspended solids into the receiving water; the suspended solids result from erosion of unstable soils from the watershed.

2. Water Quality Measurements: TS/TSS, TOC, BOD, and COD.

If areas are fertilized: NH_3-N, organic N, and phosphorus.

3. Process Description Parameters: acres of grassland with flat or gently rolling terrain, acres of grassland with hilly terrain, acres of forested land with flat or gently rolling terrain, acres of forested land with hilly terrain, rainfall intensity, rainfall amount, duration of continuous rain, soil moisture conditions, time of year, terrain, vegetative cover, and acres of fertilized land, and runoff volume/terrain category.

4. Type of Sample Required: The unconfined nature of natural area runoff requires a grab-sampling program. Multiple grab samples should be taken at several points during or immediately following a moderately intense rainstorm.

Field Training and Maneuver Area Runoff

1. Description: Field training and maneuver areas are basically natural areas which are used for troop training activities. Runoff from these areas is very similar to natural area runoff. In intensive training areas, runoff may contain a higher amount of suspended solids because of increased erosion and ordnances in impact areas may present a potential hazard due to heavy metals or propellant organics.

2. Refer to *Natural Area Runoff* section for listings of water quality and process description parameters, and a discussion of sampling requirements.

Construction Site Runoff

1. Description: Construction site runoff, which consists of runoff from areas that have been stripped of vegetation for preliminary grading, contributes large amounts of suspended soil to the receiving stream. The amount of suspended soil depends on the terrain of the land, the erodibility of the soil, and the amount of rainfall.

2. Water Quality Measurements: TS/TSS.

3. Process Description Parameters: area (acres) of stripped vegetation for construction (percent hilly or rolling; percent flat or gently rolling), rainfall intensity, rainfall amount, duration of continuous rain, soil moisture condition, time of year, overland distance to receiving water, and runoff volume.

4. Type of Sample Required: A program of grab samples at several locations is required. Samples should be taken during or immediately following a moderate rainstorm.

Land Drainage

1. Description: This runoff consists of excess irrigation or field drainage water from lands leased for cultivation. Irrigation runoff is prevalent in the southeastern United States and the states west of the Missouri and lower Mississippi Rivers; the amount of runoff depends on the amount of water intercepted by surface vegetation, the amount of water infiltrating the soil, and the amount of evaporation. Field drainage is prevalent in areas with high water tables, in drained swamps, or in flooded rice fields; the amount of drainage depends on the location of the water table.

2. Water Quality Measurements: TS/TSS, TKN, NO_3-N, phosphorus, BOC, TOC, and COD.

If pesticides or herbicides are applied, runoff concentrations should be monitored.

3. Process Description Parameters: volume of irrigation water pumped/day and irrigation water recycling practices.

For irrigation runoff: amount and type of pesticide or herbicide applied, volume of drainage water, gravity or pumped drainage, time of year, and amount of rain during preceding week (antecedent rainfall).

For field drainage: Volume of field drainage water.

4. Type of Sample Required: A grab-sampling program is recommended for evaluating both irrigation runoff and field drainage. Investigation of irrigation runoff requires multiple grab samples at outfall points during irrigation periods; for field drainage investigations, multiple grab samples should be taken at field tile outfalls or at pump outlets during periods of active drainage.

Snowmelt

1. Description: Snowmelt runoff results from the melting of snow and ice. In the cantonment area, it is collected by the stormwater drainage system. The primary contaminant of cantonment snowmelt water is the salt applied to roads to inhibit ice formation.

Unlike stormwater runoff, snowmelt runoff is usually distributed over a longer time period; the volume produced at any given time depends on the amount of snow, the ambient temperature, the solar radiation, and the existence of rainfall.

2. Water Quality Measurements: conductivity (TDS) and salinity.

3. Process Description Parameters: maximum daily temperature, average daily temperature, rainfall intensity, depth of snow cover, area (acres) serviced by stormwater drainage system, amount of road salt applied, and volume of snowmelt.

4. Type of Sample Required: A program of multiple grab samples at storm sewer outfalls is recommended. Samples should be taken only on days when snowmelt occurs in large quantities.

Landfill Leachate

1. Description: Landfill leachate is water which has infiltrated into the landfill and been collected by the underdrainage system. The leachate contains the water-soluble portions of landfilled material.

The amount of leachate depends on the amount of infiltration and the extent to which the landfill is saturated. The amount of infiltration depends on the amount of rain and type of cover material used. Regions having sufficient infiltration to produce leachate are the Pacific Northwest, New England, the Middle Atlantic states, and the Southeastern states. The southwest portion of the United States has no landfill leachate problems due to its low infiltration level.

2. Water Quality Measurements: pH, hardness ($CaCO_3$), phosphorus, TKN, organic N, COD, SO_4, TS/TSS, heavy metals (Fe, Zn, Cr, Pb), and chloride.

3. Process Description Parameters: type of soil, age of landfill, amount of annual rainfall, infiltration rate through covering material, depth of landfill, soil type of confining layer, type of underdrainage system, area of landfill, volume of solid waste filled/day, and volume of leachate produced.

4. Type of Sample Required: Grab sampling during periods of high leachate production is recommended.

6 SAMPLING GUIDELINES

Three basic decisions must be made in establishing any sampling program: (1) the type of sample required must be selected; (2) a schedule for collecting samples must be developed; and (3) sampling point locations must be selected. This chapter provides guidance in all three areas.

Selecting Sample Type

The three basic types of samples are grab, composite, and continuous. A **grab sample** is taken at random to define the condition of a portion of the sampled medium at a specific time under specific conditions. Grab samples are used when the concentrations of the investigated contaminants are relatively unstable or when immediate analysis or sample preservation is required. Multiple grab samples taken at fixed intervals—based on either time or flow—are called discrete samples. Discrete sampling can be used when investigated contaminants are relatively stable.

Table 6

Selection of Sample Type for Waste Source Investigations

	Survey Objective			
Nature of Source	**Regulation Compliance Testing***	**Environmental Impact Assessment**	**Design Criteria**	**Problem Evaluation**
Matched cycles	TC, TD	G, TC, TD	TC	G, TD
Unmatched cycles	FC, FD	FC, FD	FC	G, FD
Regular plus intermittent	C	FD, TD	FD, TD, C	G, FD, TD, C

*Normally determined by regulatory authority; use table in absence of other guidance.

TC—Time composite
FC—Flow composite
C—Continuous
FD—Flow discrete
TD—Time discrete
G—Grab

Composite samples consist of a series of grab samples collected at specified intervals and mixed together in a common storage container. Such samples collected at timed intervals are called time-composite (or standard-composite) samples; those collected on the basis of flow are known as flow-composite (or proportional-composite) samples. Composite sampling is used when the concentrations of the investigated contaminants vary randomly. Contaminants requiring immediate analysis or sample preservation cannot be collected this way.

Continuous sampling is the collection and simultaneous analysis of a portion of the investigated medium. Continuous sampling is by far the most accurate record of variations in contaminant concentrations, but its application is limited to contaminants capable of being measured by in-situ methods, which involve measuring the contaminant as it naturally occurs. Continuous sampling is used only when a constant check on contaminant levels is required; otherwise, discrete samples and in-situ analysis methods can be employed.

Selection of sample type depends on the media being investigated. In wastewater sampling, sample type depends on the nature of the waste source. In stream sampling, it depends on the factors controlling variations in contaminant concentrations in the stream.

Three basic types of confined waste sources can be sampled: (1) flow and contaminant concentration vary in matched cycles, (2) flow and contaminant concentration vary in cycles of different frequencies, or (3) either flow or contaminant concentration varies in regular cycles with an intermittent flow or contaminant slug being randomly added. Table 6 provides guidance for selecting the appropriate sample type(s) for waste source investigations. Without knowledge of the nature of the waste source, it can be assumed that domestic and commercial sources follow matched cycle patterns and that industrial sources follow regular plus intermittent patterns.

In stream sampling, four conditions determine the state of contaminant concentration: (1) the stream flow controls the amount of contaminant, (2) some known discharge from a waste source controls the contaminant level, (3) the contaminant level is controlled by a random discharge from a known or unknown waste source, (4) natural occurrences such as temperature, time of day, season, or weather control contaminant levels. Table 7 provides guidance in selecting the appropriate sample types, depending on control situation and survey objective.

Sample Scheduling

Three decisions must be made in developing a sampling schedule: (1) the total number of samples to be gathered at each station must be determined; (2) the frequency, duration, and timing of the sampling program must be established; (3) the protocol of sample collection must be defined.

Number of Samples

To determine the number of samples required at each sampling point, a preliminary sampling program must be undertaken using the selected sample type. In this preliminary program, four sampling sets are taken at each sampling point over the time period of interest. Each sample set is analyzed for each contaminant under investigation. For each con-

Table 7

Selection of Sample Type for Stream Investigations

	Survey Objectives			
Control Situations	**Regulation Compliance***	**Environmental Impact Assessment**	**Design Criteria**	**Problem Evaluation**
Flow-directed	FC, FD	FC, FD, G	FC	G, FD
Process-directed	TC, TD	TC, G, TD	TC	G, TD
Random discharge	C	FD, TD	FD, TD, C	G, FD, TD, C
Natural	TC, TD	TC, TD, G	TD, TC	G, TD

*Normally determined by regulatory authority; use table in absence of other guidance.

TC—Time composite G—Grab
FC—Flow composite FD—Flow discrete
C—Continuous TD—Time discrete

taminant, the sample mean ($\bar{x}$) is determined by

$$\bar{x} = \Sigma x_i / n$$

where n = number of samples (four for grab or composite samples, and four times the number of discrete samples drawn during a sample period for discrete samples)
x_i = contaminant concentration.

The sample standard deviation (S_x) is

$$S_x = \left[\sum_{i=1}^{n} (x_i - \bar{x})^2/(n-1) \right]^{1/2}$$

The total number of samples (N) required for certain levels of confidence is computed according to

$$N = \left[\frac{Z S_x}{L} \right]^2$$

where Z = statistical value from Table 8
L = preselected allowable error.

The number of samples required decreases as the allowable error increases or confidence level decreases.

Since each contaminant requires a different number of samples, adjusting them to some common number may be advisable. Funding, manpower, and/or time limitations may also necessitate adjustments in total sample size. To maintain confidence in the estimate of the mean, it is wiser to decrease total sample population by increasing error limits rather than decreasing confidence level.

The following example shows how to determine number of samples:

It is necessary to design a phosphate pretreatment process for the base laundry. The laundry wastewater flow and phosphate concentration exhibited matched cycles. The results of four preliminary time-composite samples analyzed for phosphates were 356 mg/l, 342 mg/l, 375 mg/l, and 368 mg/l. How many samples must be taken to get an estimate of the mean ± 10 mg/l with a 90 percent confidence level?

Table 8

Z Values for Different Confidence Intervals

% Confidence	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**9.9**
90	1.64	1.69	1.75	1.81	1.88	1.96	2.05	2.17	2.33	2.58	3.19
80	1.28	1.31	1.34	1.37	1.41	1.44	1.48	1.51	1.56	1.59	—
70	1.04	1.06	1.08	1.11	1.12	1.15	1.18	1.21	1.23	1.25	—
60	0.84	0.86	0.88	0.89	0.92	0.93	0.95	0.97	0.99	1.02	—
50	0.67	0.69	0.71	0.72	0.74	0.76	0.77	0.79	0.81	0.82	—

Calculate the mean and standard deviation:

$$\bar{x} = \frac{\Sigma x_i}{n} = \frac{1441}{4} = 360.25 \text{ mg/l}$$

$$S_x = \left[\sum_{i=1}^{n} (x_i - x)^2/(n-1) \right]^{1/2} = [628.74/(4-1)]^{1/2}$$

$$= (209.58)^{1/2} = 14.48 \text{ mg/l}$$

Calculate the number of samples required:

$$N = \left(\frac{Z\,S_x}{L}\right)^2 = \left[\frac{(1.64)(14.48)}{10}\right]^2$$

$$= (2.37)^2 = 5.64 \text{ or } 6 \text{ samples}$$

Frequency, Duration, and Timing of Program

The timing of a sampling program depends on the objectives of the survey. Waste source investigations should be undertaken during periods of stable wastewater production. If the investigated waste-producing process operates only at certain times, the sampling program should reflect this. In stream investigations, timing depends on the control situation. Flow-directed parameters should be investigated during periods of low flow, high flow, and stable hydrographs. Process-directed parameters should be investigated under critical conditions of flow, temperature, and pollution load, and, wherever possible, during periods of stable hydrograph and stable wastewater production. The random discharge situation should be investigated during stable-flow hydrograph periods. Naturally controlled parameters should be investigated under conditions which result in their maximum impact and, whenever possible, during stable hydrograph periods. For regulation compliance investigations, the regulatory agency may define the total number of samples and the sampling period to be used.

The frequency of sampling depends both on the nature of the waste source under survey, the available resources, and the type of sampling employed. Time-composite samples, for example, should reflect the cyclic nature of the wastewater being investigated. Most time composites have durations of 4, 8, 12, or 24 hr, with samples being collected every 0.5, 1, or 2 hr. Flow-composite and flow-discrete samples are collected at intervals which reflect the flow cycles of the wastewater being investigated. Time-discrete samples should, where possible, be matched to the cyclic production of wastewater or, in cases where the cycle is unknown, the sampling interval should be based on real time. Most time-discrete samples are collected at 0.5-, 1-, or 2-hr intervals. Grab samples are usually collected during the occurrence of a pollution event or at a certain time each sampling day. Frequency of grab sampling depends on the nature of the program and on available manpower. When dealing with regulatory agencies, sampling frequencies may be specified.

The duration of a sampling program is usually dictated by available resources, time allocation, or the duration of critical pollution conditions. In the absence of any of these limiting conditions, duration can be defined by dividing the total number of samples to be taken by the frequency of sampling.

Sampling Protocol

The sampling protocol defines the sampling point location, the quantity of the sample, and the field activities to be undertaken. Sampling point location guidelines are provided later in this chapter. The survey supervisor must determine sample collection times based on the sampling frequency guidelines previously provided.

Samples can be collected from pipes, channels, sewer manholes, or stream-courses, preferably in areas where the flow is well-mixed vertically and laterally. Areas with incomplete mixing must be sampled by dividing the wastewater flow into several vertical sections of equal flow, and sampling each as specified. Care must be taken to admit only the sampled liquid and exclude all extraneous material from the surface (scum and grease), sides, or bottom (settled solid or biological growth). When sampling for dissolved gas determinations, care must be taken not to agitate the sample when removing it from the medium. If possible, all dissolved gases should be measured using in-situ techniques.

The quantity of sample to be gathered depends on the contaminant being investigated and the analytical technique being employed. Table 9 provides a list of parameters and the volumes of sample required for their analysis. It is always best to refer to instructions on the analytical procedure to be employed to insure that sufficient sample is being collected.

Field activities include sample preservation and field analysis of certain parameters. Table 10 lists sample preservation directions keyed to specific

Table 9

Volumes of Wastewater Required for Contaminant Analysis*

Parameter	Analytical Method	Minimum Sample Volume
Acidity	Potentiometric titration Methyl-orange/phenolphthalein titration Direct pH measurement	100 ml**
Alkalinity	Potentiometric titration Methyl-orange phenolophthalein titration	100 ml**
Arsenic	Silver diethyl-dithio-carbonate	50 ml**
Barium	Atomic absorption	50 ml*
Beryllium	Atomic absorption	50 ml**
Boron	Curtumin Carminic acid Mannitol titration	10 ml**
BOD		300 ml**
Cadmium	Atomic absorption	100 ml**
Calcium	Gravimetric	100 ml**
COD	Titrametric Autoanalyzer	100 ml**
Chloride	Mercuric nitrate	200 ml**
Chlorinated Hydrocarbon Pesticides	Gas chromatography	1000 ml
Chromium (+6)	S-diphenylcarbazide Atomic absorption	50 ml**
Total Chromium	Atomic absorption	50 ml**
Color	Platinum-Cobalt Color disc	50 ml**
Copper	Cuprethol Atomic absorption	100 ml**
Cyanide	Pyrazolene	100 ml (1000 ml if total cyanide)
Fluoride	Autoanalyzer complexone Zirconium alizarin Autoanalyzer SPADNS	50 ml**
Hardness	EDTA titration Calculation	100 ml** None
Iron	Phenanthroline Atomic absorption	50 ml
Lead	Dithizone	50 ml
Magnesium	Atomic absorption	50 ml**
Manganese	Periodate	50 ml
Mercury	Flameless atomic absorption	100 ml
MBAS	Methylene blue extraction	500 ml**
Nitrate (NO_3)	Phenoldisulfonic acid Autoanalyzer, reduction, diazotization-coupling	50 ml
Nitrite (NO_2)	Griess-diazo (Saltzman) Oxidation Autoanalyzer diazotization-coupling	50 ml
Ammonia (NH_3)	Direct Nesslerization Phenate Distillation titration	500 ml
Organic nitrogen (Kjeldahl)	Digestion-distillation Titration or Nesslerization	500 ml
NTA (nitrilotriacetic acid)	Zinc-Zincon	100 ml
Odor	Organoleptic	200 ml**
Oil and grease	Hexane extraction Trichloro-trifluoromethane extraction Infrared analysis after carbon tetrachloride extraction	500 ml
pH	Direct potentiometric	50 ml**
Phenols	Amino antipyrine Extraction-photometric	1000 ml
Ortho-phosphorus	Heteropolymolybdenum blue	100 ml
Phosphates	Acid-persulfate digestion Heteropolymolybdenum blue	100 ml
Potassium	Atomic absorption	50 ml
Silver	Atomic absorption	50 ml
Solids	Evaporation-weight Ignition-weight	100 ml**
Selenium	Piazselenol Chromophotometry	1000 ml**
Silica	Silicomolybdate	100 ml**
Sodium	Atomic absorption	50 ml**
Specific Conductance	Wheatstone bridge	50 ml**
Sulfate	Turbidimetric Gravimetric Autoanalyzer-barium	50 ml**
Sulfide	Titrametric Colorimetric Specific ion electrode	100 ml**
Turbidity	Jackson candle Nephelometry	500 ml**
Vanadium	Gallic acid	50 ml**
Zinc	Atomic absorption	50 ml**

*From R. V. Coyne, J. M. Campbell, and E. G. Robles, *Water Sampling Guidelines and Interpretation of Data,* Report #72M-5 (USAF Environmental Health Lab, McClellan AFB, 1972).

**May be included in composite sample.

Table 10

Preservation Techniques*

Parameter	Preservation Method	Maximum Storage Period
Acidity	Refrigerate at 4°C	24 hr
Alkalinity	Refrigerate at 4°C	24 hr
BOD	Refrigerate at 4°C	24 hr
Cadmium	5 ml HNO_3/liter	Indefinite
Calcium	None	7 days
	5 ml HNO_3/liter	Indefinite
COD	2 ml H_2SO_4/liter	7 days
Chloride	None	7 days
Chlorinated Hydrocarbon Pesticides	None	24 hr
Chromium (+6)	None	3 days
Total Chromium	2 ml H_2SO_4/liter	Indefinite
Color	Refrigerate at 4°C	24 hr
Copper	5 ml HNO_3/liter	Indefinite
Cyanide	NaOH to pH 10	24 hr
Fluoride	None	7 days
Hardness	None	7 days
	5 ml HNO_3/liter	Indefinite
Iron	5 ml HNO_3/liter	Indefinite
Lead	5 ml HNO_3/liter	Indefinite
Magnesium	None	7 days
	5 ml HNO_3/liter	Indefinite
Manganese	5 ml HNO_3/liter	Indefinite
Mercury	5 ml HNO_3/liter, odd HNO_3 to bottle before sample	10 days
Nitrate (NO_3)	40 mg $HgCl_2$/liter, freeze	7 days
Nitrite (NO_2)	40 mg $HgCl_2$/liter, freeze	7 days
Ammonia (NH_3)	40 mg $HgCl_2$/liter, freeze	7 days
Organic Nitrogen (Kjeldahl)	40 mg $HgCl_2$/liter, freeze	7 days
NTA	40 mg $HgCl_2$/liter, freeze	24 hr
Oil and Grease	2 ml H_2SO_4 in glass bottle	Variable—analyze as soon as possible
Phenols	1 g $CuSO_4$, 1 ml H_3PO_4/liter, freeze	24 hr
Ortho-phosphate	40 mg $HgCl_2$/liter, freeze	7 days
Total phosphate		
Silver	5 ml HNO_3/liter	Indefinite
Sulfate	Refrigerate at 4°C	7 days
Sulfide	2 ml zinc acetate (10 percent/liter)	7 days
	Sodium acetate to bring pH balance to 7.0	
Turbidity	None	7 days
Vanadium	None	7 days
Zinc	5 ml HNO_3/liter	Indefinite

*From R. V. Coyne, J. M. Campbell, and E. G. Robles, *Water Sampling Guidelines and Interpretation of Results,* Report #72M-5 (USAF Environmental Health Lab, McClellan AFB, 1972).

parameters. The following parameters should be determined in-situ: DO, DCO_2, pH, temperature, ORP, and specific conductivity (TDS). It is also desirable to analyze the following parameters in the field: color, sulfide, acidity, alkalinity, turbidity, and cyanide.

Sample Point Location

Guidelines for sample point location for waste source investigations and stream investigations are discussed separately in the following sections.

Waste Source Investigations

In waste source investigations, wastewater is collected by a series of partially filled conduits. In most cases, drainage or sewer maps that show the layout and location of these conduits are available. Selection of sampling stations along the conduits involves locating access points which fulfill survey requirements. These access points will usually consist of manholes, open channels, and outfall points.

It is preferable to select the access points closest to the waste-producing process or activity being investi-

gated. In selecting such points, it must be determined that no other processes add wastewater to the investigated flow. Questions concerning the direction of wastewater flow, suitability of access points, or correctness of sewer maps can be answered by adding a tracing element, such as dye, floating styrofoam, or ping pong balls, to the questionable contributing processes.

Sampling below a weir, Parshall flume, hydraulic jump, or constriction gives a well-mixed medium. However, it should be noted that settleable solids will be deposited on the upstream side of these obstructions. Dissolved gas determinations cannot be made on the downstream side because turbulence induced by the constrictions increases the concentration of dissolved gases.

Samples from wide channels should be collected from the middle third (vertically) of the channel. This point should be rotated across the channel, taking care to avoid the channel sides. Sampling points should be upstream of bends or downstream at a distance from the bend equal to 10 times its width.

Sampling points should be easily accessible and relatively hazard-free. Periods of batch dumping which create a surge in the sewer should be noted to prevent accidents caused by inundation. Slippery or slime-covered steps in manholes should be noted to prevent falls. Possible existence of poisonous gases or toxic chemicals should be identified, and protective measures taken.

Stream Investigations

The ideal sampling-station in a river or stream would be a cross section from which samples at all points yield the same concentrations of all constituents, and a sample taken at any time yields the same concentrations as one taken at any other time. However, variations in water quality with time are evident in every river and stream, and samples must be collected at the proper frequency to insure representative results. On the other hand, it is not uncommon to find conditions in flowing waters where vertical and lateral mixing are complete and a single sample from a stream cross section is sufficient for water quality observation. While it is rarely necessary to sample at several depths in a stream because of incomplete vertical mixing, incomplete lateral mixing frequently occurs at one or more stations below a waste or tributary stream. If lateral mixing is incomplete (this can be determined by analyzing samples taken at various points on the cross section using a dye added to the waste or tributary inflow), multipoint sampling across the stream section must be employed.

The most accurate method of mutipoint sampling involves measuring stream velocities at numerous points on the cross section and dividing the cross section into several subsections with equal flow. The individual sampling points are then located at the centers of mass for subsections of equal flow. In most routine stream studies that require multipoint sampling, sampling points are established at approximate quarter points or other evenly spaced intervals across the width of the stream. If there are quiescent or eddy areas, the intervals should be across the main current rather than across the entire width of the stream. Restricted cross sections, for example a culvert under a roadway, are preferred locations, since vertical and lateral mixing are intensified there.

If lateral mixing is complete, a single midcurrent sampling point is adequate for most streams; however, in wide streams and rivers, it is good practice to sample at quarter points.

Sampling the edge of the stream from the bank should be avoided if possible, since the water is not representative of the main flow. If sampling from the bank is unavoidable, collections should be taken from the outside of bends where the current flows along the banks.

Measuring pollution effects at points in the main stream immediately below a waste source or tributary stream is highly impractical because of incomplete lateral mixing for some distance downstream. Sampling near the outfall may be desirable for certain types of analysis, such as determinations of total loadings of waste constituents, but such samples should not be used to assess ambient water quality. Conditions where waste inflows hug the stream bank for considerable distances with little lateral mixing should be corrected by use of diffusers at the outflow point.

In relatively small streams, physical characteristics such as wind direction, water depth, stream temperature, wetted perimeter, velocity of flow, substrate character, air temperature, and vegetative cover are best determined by making channel cross sections about every 0.5 mile (804.67 m) in noncriti-

cal areas and every .25 mile (402.34 m) in critical areas. Critical areas are those which contain unusual deterioration and/or usage of the water. The date and time of all observations should be noted so that correlations can be made with stream flow recorded by USGS or other stream flow-measuring stations corresponding to the prevailing river discharge. For large streams and rivers, USGS or state water resource agency gauging stations may furnish discharge data useful in calculating pollution loads and determining the self-purification potential of the water course.

Because the sampling station must be accessible, bridges are popular sampling sites. However, while bridges enable sampling to be conducted easily at any point or points across the width of the stream, they are positioned on the basis of traffic patterns rather than sources of wastes and tributaries. Since accessibility is only one of several factors to consider in selecting sampling stations, the suitability of bridges for sampling depends on the objectives of the study. For example, a monitoring station for a baseline record of water quality can be shifted up- or downstream several miles to permit use of a convenient bridge. On the other hand, stations for monitoring waste discharges may necessarily be rather narrowly defined; in many instances, it is necessary to deploy a boat from a bridge or walk.

If a single station is selected for monitoring, the station should be beyond the limits of the mixing zone, but close enough downstream from the investigated waste source so as not to have intervening wastewater outfalls. A series of related stations should be employed if practical in terms of the number of personnel assigned to the study and the number of analytical determinations required. The series of stations can be used to establish the course of pollution and water quality changes throughout a section of river, with data from each station supporting and reinforcing those from the other stations. The stations in a series should be at intervals based on time of water travel rather than distance traveled, although other factors such as lack of mixing of wastes in tributary streams, accessibility, and type of determinations to be made may take precedence in the exact spacing of stations.

Establishing stations where marked changes in physiography of the stream channel occur is desirable. For example, a stream reach between two adjacent stations should not include a long rapids section and a long section of deep, slowly moving water. More would be learned about the natural purification characteristics of the stream by including a third station between the rapids and the slow-moving section. A minimum of three stations located between any two points of major change in the stream is a desirable precaution, even when the time of travel between the points of change is short. Major changes include waste outfalls, tributary inflows, and significant differences in physical channel characteristics. The use of three stations is especially important when rates of change of unstable constituents are being determined. A control station upstream of a waste outfall is as important as the stations below the point of waste inflow and should be chosen carefully to insure representative results.

Sampling every tributary that enters a main stream study area is not generally feasible. A tributary with a flow less than 10 to 20 percent that of the main stream need not be sampled unless it is badly polluted or has some natural characteristic markedly different from the main stream. The station in the tributary should be as near the mouth as feasible. Positioning two or three stations on the tributary to establish rates of change of unstable constituents may be desirable if it is necessary to project data on unstable constituents from the tributary to the main stream. Care should be exercised to avoid collecting water from the main stream that flows into the mouth of the tributary.

Personnel and facility limitations may prevent collection of samples from all desirable stations or points or the examination of the desired number of samples. Decreasing the number of stations in a stream section from the optimum by increasing the spacings between stations is usually preferable to reducing the length of the reach, the number of points on cross sections where lateral mixing is incomplete, or the frequency or total number of sampling runs.

Using a few locations to provide enough samples to permit statistical analysis of results is more reliable than having many stations with only a few samples from each. It is generally better to sample intensively during a relatively short interval (about 1 wk) when the river regime is stable, than to average results from a wide range of flow conditions, which is apt to be misleading and inaccurate. A week of intensive sampling usually provides enough samples (20 to 30) for statistical treatment of data only during a period of steady flow. The most probable season for such periods can be determined from

statistical analysis of past hydrographs. However, the normal discharges of pollution sources must be occurring during the study period.

Rivers which are wide, deep, or nonuniform in flow and waste distribution must be sampled at different points across the channel sections, thus requiring a greater number of samples to obtain reliable estimates of individual parameters. The common practice is to select three evenly spaced points across the river section and sample each point at the 20 percent and 80 percent depth intervals. These depths are chosen to obtain average velocities in the vertical cross section. For shallow waters (less than about 6 ft [1.83 m]), one sample at the 60 percent depth interval is generally sufficient, but due to density differences, currents, and physical peculiarities of certain wastes, multidepth sampling is encouraged. The additional sampling depths can be eliminated after the first few collections if the results show no significant differences under any stream flow and waste inflow conditions.

Lakes and Reservoirs

Water quality variations with depth are much more apparent in lakes and reservoirs than in rivers or streams; seasonal variations are also more pronounced. Chemical distributions within a lake during spring and fall overturn periods differ significantly from those present during summer or winter stratification. The high concentrations of some dissolved nutrients and gases decrease markedly as a lake circulates. Sampling should be conducted both during periods of overturn and when stratification exists. As with rivers, physical and hydrologic parameters influence the water quality greatly. Factors which are particularly important are precipitation and runoff from the watershed, tributary inputs, groundwater inputs, area, depth, and wind exposure.

7 FLOW MEASUREMENT

Collection of flow information is an important part of any water/wastewater survey. Flow data are used to determine the quantity and variability of wastewater discharges, the total mass of pollutants discharged, and the impact of the discharge on the receiving stream. This chapter briefly discusses flow measurement for confined waste sources, unconfined waste sources, and streams. Prior to undertaking flow measurement, however, more detailed references listed in the *Recommended Bibliography* should be consulted.

Confined Waste Sources

Direct Measurement

The two types of confined source flow are **pressure flow**, which is typically found in water supply lines and pressurized sewers, and **gravity flow**, which is typically found in free flowing sewers and open channels.

Pressure flow can be measured by several different methods:

1. Turbine meter—typical water meter; useful in small lines; element can be rotated in relation to flow.

2. Venturi meter—pipe insert consisting of converging inlet section, throat, and diverging outlet section; flow is related to pressure differential between the inlet and the throat.

3. Flow nozzle—nozzle is inserted inside pipe; flow is related to pressure differential between pipe and nozzle.

4. Orifice—thin plate with a hole or tube extending out of the middle; flow is related to the pressure differential on each side of the plate.

5. Pitot tube—small-diameter tube with a right-angle bend; placed in the center of a straight pipe; flow velocity determined by pressure differential between flowing fluid and dormant fluid; flow is calculated by multiplying flow velocity by cross-sectional area of pipe; not useful for measuring flow in wastewater containing solids.

6. Magnetic meter—electromagnetic field is set up in the pipe; flowing liquid produces a voltage which is related to flow velocity; flow can be calculated by multiplying velocity by cross-sectional area of the pipe.

7. Rotameter—flow is diverted through a vertical tapered tube containing a metal ball; flow is related to the distance the ball is raised in the tube; not useful for measuring flow in wastewater containing solids.

Gravity flow can be measured by several different methods:

1. Orifice—thin plate with a hole in the center; placed at the end of a full flowing pipe; upstream pressure is related to flow.

2. Weir—thin plate with a notch (rectangular, trapezoidal, or triangular) cut out of the middle; water is forced to flow through the notch; flow is related to the depth of water in the notch.

3. Flow nozzle—nozzle is placed at the end of a full flowing pipe; flow is related to height of water upstream.

4. Parshall (Venturi) flume—consists of a converging section, throat, and diverging section; flow is related to throat width and height of water in the converging section.

5. Palmer-Bowlus flumes—control section constricts flow; flow is related to flume width, upstream depth, and wetted cross-sectional area of flume.

6. California-pipe—measures flow from open end of a horizontal pipe; flow is related to pipe diameter and water depth.

7. Computation—flow can be estimated from the slope of a free-falling liquid and the wetted area of a pipe.

8. Chemical and radioactive tracers—flow can be determined by knowing the dilution of a tracer and the tracer addition rate.

9. Velocity measurements—flow can be calculated from velocity measurements and wetted area; velocity can be determined by current meters, pitot tubes, floats, or tracers.

Indirect Measurement

Wastewater flow can be approximated by several methods. Factors are available for relating wastewater volumes to some wastewater-producing activities (e.g., 40 gal of wastewater per wash for an automatic clothes washer) and wastewater volumes can be estimated by noting these activity levels. For a system which produces wastewater in batches, wastewater volume can be approximated by noting the changes in the water levels in a reservoir. For a system where all water-consuming activities have been identified, wastewater volumes can be approximated by monitoring incoming water supply lines and subtracting water consumption. For systems where wastewater is removed by pump, wastewater volumes can be estimated using pump capacity curves and pump operation time.

Interpretation of flow data requires information on the periodicity of flow and the factors controlling flow. Flow periodicity can follow three basic patterns—continuous, periodic, and random. Continuous flow, which is characterized by a constant flow of water or wastewater, can have a stable, cyclic, or irregular flow rate. In defining continuous flow, the type of flow rate must be identified along with any factors which control the level of flow and any identifiable flow cycle. For varying continuous flow situations, periods of high, low, and average flow must be defined.

Periodic flow is defined as an intermittent flow which follows some predefined cycle. To characterize periodic flow it is necessary to define the flow cycle, duration of flow, and flow rate. Information on the factors or activities controlling periodic flow will facilitate understanding how the flow is produced.

Random flow occurs at irregular intervals. In characterizing random flow, it is necessary to define the total flow per usage period, as well as the factors resulting in flow. Information on the relative frequency of flow occurrences can be useful in approximating the total flow during some particular time period (e.g., one day).

Unconfined Waste Sources

Flow from unconfined sources is similar to gravity flow from confined sources and the same basic techniques are used to measure it. Flow measurement is difficult because unconfined sources generate wastewater over a broad area. In most situations, the measurements can be made only in areas serviced by some centralized collection system such as storm sewers in cantonment areas, collection ditches in irrigated areas, field tile systems in land drainage areas, and leachate underdrainage systems for landfills. After the collection system outfall point has been located, the area serviced by that system must be defined by locating the natural drainage divides. This can be done by referring to a 7.5 minute USGS topographic map of the area under study. Since unconfined flow is highly irregular and intermittent, it is necessary to measure the total flow per discharge event.

Additional information must be gathered to facilitate interpretation of unconfined flow measurements. Stormwater measurements require information on the amount of continuous rainfall, rainfall duration, length of time since the last rainfall, predominant land use, and season of the year. Irrigation drainage measurements require information on the amount of irrigation water applied and the length of time since last rainfall. Field tile drainage measurements require data on the length of time since the last rainfall and the season of the year. Leachate drainage measurements require information on age and depth of landfill, type of covering soil, and season of the year. Snowmelt measurements need information on depth of snow cover, amount of rainfall (if any), and average daily temperature.

Since measurement of unconfined flow from areas not serviced by a centralized collection system is extremely difficult, techniques have been developed for estimating stormwater and snowmelt flows. The techniques described here are a modified Rational Method for estimating stormwater flow and a modified Corps of Engineers technique for estimating snowmelt flow.

A modification to the traditional Rational Method of computing runoff rates relates total runoff volume to rainfall quantity according to the formula:

$$V_T = 60\,CV_rAt$$

where V_T = total runoff volume, cu ft
C = average runoff coefficient from Tables 11 and 12
V_r = quantity of rainfall, in.
A = drainage area, acres.
t = duration of continuous rainfall, min.

Rainfall quantity is defined as the total amount of continuous rainfall falling on the drainage area. The drainage area should be fewer than 5000 acres and be serviced by a perennial stream or centralized collection system. Boundaries of the drainage area should be located on a 7.5 minute USGS topographic map. The predominant land use, general type of soil, type of vegetative cover, and general ground slopes should be defined for each drainage area. To select the appropriate runoff coefficient, first refer to Table 11, then use Table 12 to determine the appropriate value of the runoff coefficient.

It is desirable to estimate the varying rates at which stormwater runoff occurs. The Rational Method works very well for areas of fewer than 5000 acres:

Table 11

Runoff Coefficient Values for the Rational Formula*

Type of Drainage Area	Runoff Coefficient, C
Lawns:	
Sandy soil, flat, 2%	0.05-0.10
Sandy soil, average, 2-7%	0.10-0.15
Sandy soil, steep, 7%	0.15-0.20
Heavy soil, flat, 2%	0.13-0.17
Heavy soil, average, 2-7%	0.18-0.22
Heavy soil, steep, 7%	0.25-0.35
Business:	
Downtown areas	0.70-0.95
Neighborhood areas	0.50-0.70
Residential:	
Single-family areas	0.30-0.60
Multi units, detached	0.40-0.60
Multi units, attached	0.60-0.75
Suburban	0.25-0.40
Industrial:	
Light areas	0.50-0.80
Heavy areas	0.60-0.90
Parks, cemeteries	0.10-0.25
Playgrounds	0.20-0.35
Railroad yard areas	0.20-0.40
Unimproved areas	0.10-0.30
Streets:	
Asphalt	0.70-0.95
Concrete	0.80-0.95
Brick	0.70-0.85
Drives and walks	0.75-0.85
Roofs	0.75-0.95

*From *The Water Encyclopedia*, D. K. Todd, ed. (Water Information Center, 1970).

$$Q = CiA$$

where Q = stormwater discharge rate, cu ft/sec
C = runoff coefficient, from Tables 11 and 12
i = rainfall intensity, in./hr
A = area, acres.

The runoff coefficient values and drainage area values are determined as previously discussed. Information on rainfall intensity variations encountered in a storm can be obtained from the local Weather Bureau office or the state Water Survey office.

The amount of daily snowmelt can be approximated for open sites by:

Table 12

Watershed Characteristics for Determining Runoff Coefficient*

For each watershed characteristic in left column select appropriate descriptive box; add four numerical values given in parentheses to obtain runoff coefficient percentage, multiply percentage by the maximum runoff coefficient.

Designation of Watershed Characteristics	Runoff-Producing Characteristics 100 extreme	75 high	50 normal	25 low
Relief	(40) Steep, rugged terrain, with average slopes generally above 30%	(30) Hilly, with average slopes of 10 to 30%	(20) Rolling, with average slopes of 5 to 10%	(10) Relatively flat land, with average slopes of 0 to 5%
Soil infiltration	(20) No effective soil cover, either rock or thin soil mantle of negligible infiltration capacity	(15) Slow to take up water; clay or other soil of low infiltration capacity, such as heavy gumbo	(10) Normal; deep loam with infiltration about equal to that of typical prairie soil	(5) High; deep sand or other soil that takes up water readily and rapidly
Vegetative cover	(20) No effective plant cover; bare or very sparse cover	(15) Poor to fair; clean-cultivated crops or poor natural cover; less than 10% of drainage area under good cover	(10) Fair to good; about 50% of drainage area in good grassland, woodland, or equivalent cover; not more than 50% of area in clean-cultivated crops	(5) Good to excellent; about 90% of drainage area in good grassland, woodland, or equivalent cover
Surface storage	(20) Negligible; surface depressions few and shallow; drainageways steep and small; no ponds or marshes	(15) Low; well-defined system of small drainageways; no ponds or marshes	(10) Normal; considerable surface-depression storage; drainage system similar to that of typical prairie lands; lakes, ponds, and marshes less than 2% of drainage area	(5) High; surface-depression storage high; drainage system not sharply defined; large flood-plain storage or a large number of lakes, ponds, or marshes

*From *The Water Encyclopedia*, D. K. Todd, ed. (Water Information Center, 1970).

$$M = 0.06\,(T\ \text{mean} - 24)$$

$$M = 0.04\,(T\ \text{max} - 27)$$

where M = daily snowmelt, in.
T mean = average of the day's high and low temperatures, °F
T max = maximum daily temperature, °F

Snowmelt from forest sites can be approximated by:

$$M = 0.05\,(T\ \text{mean} - 32)$$

$$M = 0.04\,(T\ \text{max} - 42)$$

These correlations are applicable for T mean between 34 and 66°F and T max between 44 and 76°F. The daily volume of snowmelt can be calculated according to:

$$V_S = 3630\,MA$$

where V_S = volume snowmelt, cu ft
M = snowmelt, in.
A = land area, acres.

It should be remembered that the maximum amount of snowmelt depends on the depth of snow cover, and that 1 in. snowmelt equals 7 to 10 in. snow cover. A more detailed discussion of estimating snowmelt can be found in EM 1110-2-1406.[4]

Streamflow

Streamflow is determined by the velocity-area techniques described for open channel gravity flow.

[4] *Runoff From Snowmelt*, EM 1110-2-1406 (U.S. Army Corps of Engineers, January 5, 1960).

First, the stream is divided into several vertical sections, none containing more than 10 percent of the total flow. A current meter is used to measure the mean stream velocity for each section. Mean velocity is defined as the average of the velocities at 20 percent and 80 percent depth for stream sections deeper than 6 ft or the velocity recorded at 60 percent depth for stream sections less than 6 ft deep. The stream flow through each section can be calculated by multiplying the cross-sectional area by the mean velocity. Total streamflow is then computed by summing streamflows of the vertical sections.

Velocity should be measured in a straight section of stream having a fairly stable streamflow. Velocity measurements can be taken from a boat, an overhead structure such as a cableway or bridge, through the ice, or by wading into the stream. Wading measurements are practical only in streams less than 4 ft deep whose flow is below 12 cu ft/sec/ft width. The measurements must be taken in a straight line which is normal to the stream axis. When using the wading, boat, or ice techniques, a rope or cable should be stretched across the stream as a guide.

Streamflow discharges can be related to river stage height* by means of a stage-discharge rating curve developed by plotting stream discharge versus stage height. Streamflow can be then determined by noting the river stage height on the curve.

Use of existing streamflow gauging stations can save time and effort. Stage-discharge rating curves and stage gauging stations have been developed for many of the major rivers and streams in the United States. Information on gauged streams is gathered by U.S. Geological Survey and many state water resource bureaus.

8 RECOMMENDATIONS

It is recommended that the survey-planning and performance guidelines presented in this report be used in designing and performing water/wastewater surveys at the installation level.

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*River stage height is defined as the water surface elevation above some arbitrary zero point at a specific gauging station.

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APPENDIX:

LEGISLATIVE HISTORY

Environmental legislation regarding water has a long history characterized by infrequent and ineffective enforcement. Before 1970, the main environmental laws affecting water were the Rivers and Harbors Act, which prohibited the deposit of refuse into navigable waters of the United States, and the Federal Water Pollution Control Act, which attempted to establish water quality criteria for bodies of water in the United States.

In 1972, Congress totally revised the legislative scheme by enacting Federal Water Pollution Control Act Amendments of 1972, which superseded much of the environmental legislation previously passed. The Amendments contain the following major provisions:

1. Federal jurisdiction is extended to intrastate as well as interstate waters

2. Enforcement is based mainly on effluent limitations, rather than water quality of the stream

3. Effluent limitations are more stringent than needed for protection of waters and are intended for water improvement

4. Penalties and enforcement under the present Act should be more severe than under previous legislation

5. Responsibility for enforcement has been shifted to the Environmental Protection Agency (EPA), with more centralized control.

Section 313 of the Act requires federal departments and agencies to comply with federal, state, interstate, and local requirements regarding the control and abatement of pollution. Executive Order 11752 requires that federal facilities be in the forefront in the fight against pollution. These requirements for the control of pollution under the Act are now embodied in effluent limitations rather than in the quality of the receiving body of water.

EPA has stated that "water quality criteria and effluent limitations are the undergirders of the national water quality improvement program."[1]

[1] *Proposed Criteria for Water Quality*, Vol 1 (Environmental Protection Agency, 1973), p 16.

Since these concepts are important in upgrading the quality of the nation's waters, understanding them is important.

Water quality standards emphasize the concentration of pollutants already present in a body of water. When implemented, such standards "would prohibit any discharge which would result in a greater concentration of pollutants in the water than the maximum permitted by statute or regulation."[2]

This policy of protecting and improving waters by focusing on the whole body of water was used in legislation until 1972, when Congress shifted from water quality standards to effluent limitations with the Federal Water Pollution Control Act Amendments.[3] Effluent limitations focus on "quantitative limitations of the pollutants present in a discharge."[4] Effluent limitations prohibit a discharge of a greater concentration or volume of pollutant than allowed by statute or regulation.

The 1972 Amendments also established the National Pollutant Discharge Elimination System (NPDES), which places responsibility for developing and enforcing water pollution control programs on the states after approval by EPA. Anyone who discharges into the waters of the United States must obtain a permit from the regional EPA office. Applications for permits require that the discharge be analyzed.

The EPA regulations for NPDES also require monitoring of discharges by permit holders in the following situations:

1. A discharge which is not a minor discharge*

2. The Regional Administrator requires a discharge to be monitored

[2] Thomas B. Arnold, "Effluent Limitations and NPDES: Federal State Implementation of the Federal Water Pollution Control Act Amendments of 1972," *Boston College Industrial and Commercial Law Review*, Vol 15, No. 4, p 767.

[3] Arnold, p 767.

[4] 33 USU 1160 (c) (1970).

*A minor discharge: (1) has a total volume of less than 50,000 gal (239 m^3) on every day of the year, (2) does not affect the waters of more than one state, (3) is not identified as not a minor discharge.

3. A discharge contains toxic pollutants for which an effluent standard has been established by EPA.*

Facilities with NPDES permits are required to monitor:

1. Flow (in gallons per day)
2. Pollutants which must be reduced or eliminated under the terms and conditions of the permit
3. Pollutants which the Regional Administrator finds could have a significant impact on water quality
4. Pollutants specified in EPA regulation.

The monitoring must take place often enough to yield data which reasonably characterize the nature of the discharge.

Records of the monitoring activities and results for all samples must include:

1. Date, exact place, and time of sampling
2. Dates analyses were performed
3. Who performed the analyses
4. Analytical techniques/methods used
5. Results of such analyses.

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*Toxic pollutants for which effluent standards will be promulgated are: (1) aldrin (1, 2, 3, 4, 10, 10-hexachloro-1, 4, 4a, 5, 8, 8a-hexahydro-1, 4, 5, 8 endo-exodimethanonaphthalene), dieldrin (1, 2, 3, 4, 10, 10-hexachloro 6, 7-epoxy - 1, 4, 4a, 5, 6, 7, 8, 8a-octahydro - 1, 4-endo, exo-5, 8-dimethononaphthalene); (2) benzidene and its salts (para-para - diaminobiphenyl); (3) cadmium and all cadmium compounds; (4) cyanide and all cyanide compounds; (5) DDD (TDE) 1, 1- dichloro - 2, 2-bis(parachlorophenyl) - ethane; DDE (dichlorodiphenyldichloroethylene) 1, 1 - dichloro-2, 2-bis (para-chlorophenyl) ethylene; DDT (dichlorodiphenyltrichloroethane) 1, 1, -1- trichloro-2, 2 bis (para-chlolorpheny) ethane; (6) endrin (1, 2, 3, 4, 10, 10-hexachloro-6, 7-epoxy-1, 4, 4a, 5, 6, 7, 8, 8a - octahydro - 1, 4 - endo- endo-5, 8-dimethanonaphthalene); (7) mercury and all mercury compounds; (8) Polychlorinated biphenyls (PCBs); (9) toxaphene (chlorinated camphene).

LIST OF ABBREVIATIONS

ABS/LAS	Measure of detergents
Ag	Silver
Al	Aluminum
As	Arsenic
B	Boron
Ba	Barium
Be	Beryllium
BOD_5	Five-day biochemical oxygen demand
Br^-	Bromide
C	Continuous sample
Ca	Calcium
CCE	Carbon chloroform extract
Cd	Cadmium
CH_4	Methane
Cl	Chlorine
Cl^-	Chloride
Cn^-	Cyanide
CO_2	Carbon dioxide
COD	Chemical oxygen demand
Cr[+6]	Chromium, total and +6
Cu	Copper
DCO_2	Dissolved carbon dioxide
DFAE	Directorate of Facilities Engineering
DO	Dissolved oxygen
EPA	Environmental Protection Agency
F^-	Fluoride

FC	Flow-composite sample
FD	Flow-discrete sample
Fe	Iron
G	Grab sample
Hg	Mercury
I^-	Iodide
K	Potassium
Li	Lithium
Mg	Magnesium
Mn	Manganese
Na	Sodium
NH_3-N	Ammonia nitrogen
Ni	Nickel
NPDES	National Pollutant Discharge Elimination System
NO_2-N	Nitrite nitrogen
NO_3-N	Nitrate nitrogen
NTA	Nitrilotriacetic acid
O_3	Ozone (residual)
Organic N	Organic nitrogen
ORP	Oxidation Reduction Potential
P	Phosphorus
Pb	Lead
PO_4	Phosphates
Se	Selenium
Si	Silica
SO_3^{-2}	Sulfite
SO_4^{-2}	Sulfate
Sr	Strontium
TC	Time-composite sample
TD	Time-discrete sample
TDS	Total dissolved solids
TKN	Total Kjeldahl nitrogen
TOC	Total organic carbon
TS	Total solids
TSS	Total suspended solids
USGS	U.S. Geological Survey
V	Vanadium
Zn	Zinc

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